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Studies on the Structure of Lignite, Brown Coal, and Bituminous Coal in Japan

Contributions to Cytology and Genetics from the Departments of Plant-Morphology and of Genetics, Botanical Institute, Faculty of Science, Tokyo Imperial University, No. 70

By

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With Twenty-two Text Figures and Sixteen Plates

I. Introduction

Authors unanimously agree in the opinion that coal is chiefly composed of vegetable matter, although they differ considerably as to the kinds of plants from which it was derived and as to what parts of the plant tissue the coal-constituents belong, and also as to where they were accumulated, in other words, whether their origin was autochtonous or allochtonous. Especially as regards the exact nature of the vegetable constituents of Japanese coal our knowledge is very meagre.

The present study was begun during the author's stay in 1915 in the Laboratory of Plant-Morphology, Harvard University, under Professor E. C. Jeffrey and was there carried on for about one year.

Afterwards the study was resumed and extended under Professor K. Fujii in the Morphological Labaratory of the Botanical Institute of the Faculty of Science, Tokyo Imperial University.

The chief object of the study was the determination of the plant remains which constituted the main mass of the coal, and the state of their preservation which has an important bearing on the question of the origin of the coal.

Consequently the mineral constituents and the geological side of the study as well as other points of economical interest were left entirely untouched.

II. Material and Methods

The material of the present study consisted of bituminous coal from twenty-two different localities and brown coal and lignite from seventeen different localities, as given in the following list:

Locality	Name of Colliery	Name of Seam	Kind of Coal	Age*
Hokkaido	The Yubari coll.	Main seam	Bituminous	Tertiary
Ibaraki Prefecture	The Onoda coll.		Bituminous non-coking	„
Fukushima Prefecture	The Iwaki coll.	Nagakura seam	Bituminous non-coking	„
Fukuoka Prefecture	The Ōtsuji coll.	San-jyaku (Three-foot) seam	Bituminous	„
„	„	Takaé seam	„	„
„	„	Shi-shaku (Four-foot) seam	„	„
„	The Méo coll.	Kankan seam	„	„

* The Geological age in this list is taken mostly from 'Mining in Japan past and present', published by the Bureau of Mines, the Department of Agriculture and Commerce of Japan, 1909.

Locality	Name of Colliery	Name of Seam	Kind of Coal	Age
Fukuoka Prefecture	The Méo coll.	Shi-shaku (Four-foot) seam	Bituminous	Tertiary
„	„	Nakajimé seam	„	„
„	„	Go-shaku (Five-foot) seam	„	„
„	The Miiké coll.		„	„
Nagasaki Prefecture	The Takashima coll.	Goma-go-shaku (Goma-five-foot) seam	„	„
„	„	Banto-go-shaku (Banto-five-foot) seam	„	„
„	„	Ju-has-shaku (Eighteen-foot) seam	„	„
Yamaguchi Prefecture	The Ominé coll.		„	Triassic
Kyōto Urban Prefecture	The Maidzuru coll.		„	Jurassic
Manchuria	The Fuchun coll.	Fuji seam	„	Tertiary
„	„	Yamato seam	„	„
„	„	Asahi seam	„	„
„	„	Sakura seam	„	„
„	The Sha-ho-tsu coll.		„	Jurassic
Awaji, Hyōgo Prefecture	The Doi coll.		Brown coal	Tertiary

Locality	Name of Colliery	Name of Seam	Kind of Coal	Age
Awaji, Hyōgo Prefecture	The Kashū coll.		Lignite	Tertiary
Kyōto Urban Prefecture	The Tayama coll.		„	„
Shiga Prefecture	The Hirako coll.		Brown coal	„
„	The Kaigaké coll.		Lignite	„
Miyé Prefecture	The Hotta coll.		„	„
„	The Asahi coll.		„	„
,	The Tōtori coll.		„	„
„	The Shiraki coll.		Brown coal	„
Aichi Prefecture	The Kōzōji coll.		Lignite	„
„	The Ōkusa coll.		„	„
„	The Takahari coll.		„	„
„	The Daisenji coll.		„	„
„	The Nagakudé coll.		„	„
Nagano Prefecture			„	„?
Miyagi Prefecture	The Mukoyama coll.		„	„

Specimens of each of the bituminous coals were taken from three different depths in the corresponding seam, the first about 15 cm. below the upper surface of the seam, the second from its middle part, and the third from a point about 15 cm. above the bottom of the seam.

Method A

The bituminous coal and some of the brown coal were treated after JEFFREY's method as in the following schedules:

1. Slabs about 1 cm. thick are secured, cut parallel to the bedding plane of the seam, and then are cut into pieces about 1 cm. square or half that size.

2. These pieces, some wrapped loosely in thin strips of cotton cloth and others with no wrapping, are put into melted carbolic acid, and kept in a corked bottle in a warm bath at about 65°C. for a week.

3. The material is taken out of the carbolic acid and washed in running water for two days.

4. Then the material is put into strong hydrofluoric acid in a bottle coated with paraffin and kept for two weeks.

After this treatment some of the material, e. g. some pieces of brown coal, were immediately submitted to process 5; but for other materials e. g. the bituminous coals from Miiké, Ominé, and Fuchun, processes 2, 3, and 4 were repeated before they were passed on to the next process; while for still other material such as the coal from Takashima, processes 2 and 3 were repeated three times or the coal was treated with potassium chlorate and hydrofluoric acid for a week, then washed in running water, and again subjected to the processes 3 and 4.

5. Kept in 75% alcohol for one day.

6. Put into 95% alcohol, and after the air has been exhausted the material is kept in alcohol for one day.

7. Put into absolute alcohol for three days in a warm bath at about 65°C. the alcohol being renewed twice during the time.

8. The material then transferred to a 2% celloidin solution at about 65°C. Next into a 6% celloidin solution, and subjected to a positive pressure of 15–10 atmospheres by means of a compression pump, at room temperature, for 12 hours.

9. Put into an 8% celloidin solution at 65°C. for 24 hours. Next transferred to a 16% celloidin solution, then during three or more days at a temperature of 65°C., a few pieces of celloidin being added to the solution once a day.

10. The material is put into chloroform as usual in the celloidin method, and kept in it for 24 hours.

11. Finally it is transferred to a glycerine-alcohol (equal parts) solution.

Two, three or more days after the last treatment microtome sections of the material were made 2 to 5 micra thick, and mounted in Canada balsam.

Method B

The material is treated with the hydrofluoric acid for a week or longer and washed in running water until no trace of the acid remains in the material; it is then steeped in a mixture of equal parts of glycerine and 95% alcohol for several days; finally sections were made as in method A and cut 2–10 micra thick. In this way petrified wood may be cut neatly with a microtome.

Some material was cut without any special treatment, except that the pieces were steeped in 95% alcohol for several days, or were boiled in hot water for 5–10 minutes.

Sometimes for rough preliminary observation, as well as for the comparison of non-treated material and treated material, hand sections of raw material were used.

The sections of the coal were made generally perpendicular to the bedding plane of the seam as well as parallel to the latter. But for woody elements in coal cross, radial, and tangential sections of the tissue were made. In only one case were ground sections used.

For the study of spores and some fungi in coal SCHULZE's maceration liquid was used.

Generally unstained material was used for microscopical observations, but some sections of the woody material of lignite were stained with iron alum haematoxylin and safranin. With this stain some woody tissue, the coalification of which had not progressed too far, stained like the wood of living plants, the only difference being that it stained rather dark.

Polarized light was used to observe the degree of coalification of the material, especially in cell walls of different kinds of tissues.

The grinding method, which is generally used for the study of coal and petrified wood was not used as a rule by the present writer, for the following reasons:

First, the present study is entirely concerned with the vegetable material in coal, and not with its mineral structure, so that the loss of its mineral constituents in the celloidin treatment above described is not

disadvantageous; while the grinding method wastes too much material, so that sometimes a small but important piece is wholly ruined for study. Secondly, much thinner sections can be got by the celloidin method than by the grinding method, so that we can prepare a larger number of consecutive sections, which is an important advantage in the study of plant structure, as the plant body generally exhibits wide differentiations in transverse, longitudinal, as well as radial directions, and the later serial sections may show structure not found in those preceding. Thirdly, thinner sections show more details in structure than the thicker ones, especially in darker material, in which coalification has much advanced. Indeed it is sometimes almost impossible in such a material to make out details in ground sections. Fourthly, it is much easier to fix the orientation for the cutting in the celloidin method. Fifthly, we can stain the material or apply chemical reagents to the material cut by the celloidin method, while it seems very difficult to apply dyes and chemicals to plant material prepared by the grinding method.

III. Vegetable constituents and their state of preservation

Already in the early part of last century, Withum (1833) recognized vegetable matter in coal. Afterwards several authors reported on the vegetable constituents of coal, and various methods for the study of coal were proposed; but due to the difficulties of getting thin sections of adequate size the real nature of the vegetable constituents of coal for a long time remained undisclosed. In 1909, Jeffrey first prepared very thin sections of cannel coal by his own special method, and claimed from the study of those sections that the coal which had been supposed by Bertland and Renault (1892) and others to consist of algal remains, was in the main composed of the accumulated spores of extinct cryptogams. Since then many papers regarding the internal structure of coal have been published, and our knowledge of this subject has been considerably extended.

In Japanese coal the vegetable constituents are various, ranging from lower algae to angiospermous plants, and their tissues are often remarkably well-preserved.

A. Protoplasm and cell-contents

The protoplasm, namely the nucleus, cytoplasm, and the plastids and other organic cell contents easily decompose if they are left in the

open air, generally by the action of microorganisms, but if they are secluded from such action, although they are dead bodies, yet they are preserved for a long time. In the case of coal even WHITE and THIESSEN (1913) who are among the best known investigators of coal, say in their work " such substances as the protein, sugar and starch, decompose readily and would be removed first ". Naturally it could hardly be imagined that the protoplasm with its unchanged chemical constituents would be preserved in coal, but the ordinary structural elements of a cell are often shown clearly in the tissue of some lignite. Pl. IX, Fig. 1 shows such specimen. The tissue lying crosswise in the figure is a ray tissue of a coniferous wood in a lignite, and Pl. IX, Fig. 2 shows the corresponding tissue of a living conifer, which is supposed to belong to the same species as that of the fossil wood or to one closely related. Comparing the ray tissue of these two figures, one can easily recognize the close similarity of their cellular structures. In Pl. IX, Fig. 2, (n) represents the nucleus of a ray cell, the small grains surrounding the nucleus being the starch grains. In Pl. IX, Fig. 1 (n) exactly corresponds to (n) in Fig. 2, in position, size and shape, and is of a brown color. No plant histologist will object, I believe, to this identification. Other structural details of the cells can also be recognized, though not so distinctly.

The above mentioned cellular structure of the fossil cell, except one case which is shown in Pl. XXIII, Fig. 117, d, is, however, not clearly recognizable after the specimen has been treated with carbolic acid, hydrofluoric acid, and other agencies.

The nitrogen in the chemical analysis of the coal may possibly come from protoplasmic remains and protein substances which still persist in the cell, although with partial alteration.

The cortical parenchymatous tissue, the mesophyll, and the pith are generally much crushed, so that their histological structures are very obscure in sections transverse to the coal layers or bedding plane, but in sections parallel to the layers the details of the tissue are sometimes clearly distinguishable, though the cell cavity is filled with some homogeneous substances, and the topographical identification of different kinds of tissue is possible. Pl. IX, Fig. 3 is an example, and shows a photograph of the section of a leaf, cut parallel to its surface. The broad irregularly curving lines dividing the figure into four areas represent parts of the vascular bundles which constitute the leaf veins, and the tissue of these four areas is the mesophyll, or assimilation

parenchyma. The cell cavity is filled with a pinkish brown material, probably altered cell contents.

The preservation of resin in coal and lignite has been reported by several authors, e. g. WHITE and THIESSEN demonstrated resin by chemical reactions in bituminous coal and lignite, and WHITE inferred from this observation the preservation of resin in Palaeozoic coal.

In Japanese coal, solid extra-tissue resin as irregular masses or thin layers was frequently met with during the present investigation. The masses are sometimes larger than 5 mm. in diameter, while the layers seldom exceed 2 or 3 mm. in thickness and extend 4 or 5 cm. or more in a direction parallel to the bedding plane of the seam.

The presence of fossil resin in Japanese coal is well accounted for by the fact that the latter consists mostly of Tertiary deposits, the main mass of which is composed of coniferous wood.

We can find resin cells in almost all sections in which woody coniferous tissue is included. Compared with the other kinds of cells in the wood, the resin cell is more resistant, and consequently it is preserved even in tissues in which almost all other cells have suffered and their structures have become hardly recognizable (Pl. XI, Fig. 15 etc.). On account of this fact the resin cell is on some occasions a great help in the topographical identification of a tissue.

The deeper colored cells in Pl. IX, Fig. 1, are the resinous ray cells, and (r) in Figs. 5–8, is the resin cell.

The rest of resin in the cell, somewhat altered in substance is deep reddish brown in color, and occasionally fills the cell cavity, but in some cases it shows an alveolar appearance, so that it resembles in its superficial appearance a section of a conidium or the sclerotium of a fungus. What remains of the resin in the resin cell is slightly soluble in absolute alcohol, ether, chloroform, and petroleum ether. It stains slightly with Sudan III dissolved in 95% alcohol, alkannine solution in 50% alcohol, and 'Scharlach' R solution in 85% alcohol.

The solid resin mass in coal is very much like that of resin artificially gathered or exuded from a living conifer. It has the conchoidal fracture and resinous lustre, and is mostly bright yellow in color, but sometimes reddish brown.

The resin obtained by the evaporation of the solvent from an ether or chloroform solution stains nicely with Sudan III, fairly with alkannine, and slightly in the solution of 'Scharlach' R, as is the case with ordinary resin, but the blackening reaction with 1% osmic acid is hardly recognizable.

B. Cell wall

a. Tracheids and wood-tissue in general

Coniferous wood constitutes the main part of the composition of Japanese coal and lignite, and angiospermous wood an insignificant part. The former is homogeneous in comparison with angiospermous wood, being composed for the greater part of tracheids; while the latter is far more heterogenous, consisting of several kinds of tissue such as tracheids, vessels, wood parenchyma, wood fibers, ray tissues, etc., and is less resistant than the former. This may be a reason why angiospermous elements play an insignificant part in our coal, but it is probably chiefly due to the fact that the angiosperms formed no considerable part of the coal forming flora of the time.

The angiospermous wood in Japanese coal, as is shown in Pl. IX, Fig. 4, is generally in fragments, so it is very difficult to determine to what species it belonged. The coniferous wood in coal and lignite is of different sizes, varying from small broken twigs to quite large and old trunks. The small twigs are often found with the bark on, but the large trunks are generally denuded of it. The state of preservation varies. Some are very well preserved, so that it is possible to determine to what type of wood they belonged, but others are compressed or have become a homogeneous mass, in which no cellular structure can be detected. The comparison of these different states of structural preservation in lignite enables us to infer how the deforming processes went on.

The optical properties of the tracheidal cells. The wall of the tracheid in living conifers consists of three lamellae, primary, secondary, and tertiary. Their distinction is very clear in the wall of the summer tracheids of conifers. The primary lamella is the ligno-pectic membrane, the secondary the ligno-pecto-cellulose, and the tertiary simple cellulose. Also we have the so-called middle lamella between the individual cells, as their cementing substance. Some authors include the middle lamella among the primary lamella, but they differ from each other in their optical properties, as is apparent when a section of the tissue is examined between crossed nicols. The middle lamella does not show double refraction, while the primary lamella shows it. The double refraction is strongest in the primary lamella, weaker in the tertiary, and weakest in the secondary.

This difference in the optical behavior of the different lamellae of the wall of tracheids is retained in many cases in the well preserved coniferous wood in Japanese lignite.

Pl. X, Fig. 9 shows a microphoto of the longitudinal section of a spring wood of living Cryptomeria, which was taken with crossed nicols, with the longitudinal axis of the tracheids orientated at $+45°$ to the vibration direction of the nicols. The wall of the bordered pits shows the phenomenon of double refraction. Between crossed nicols dark cross bars appear traversing each pit parallel to the vibration direction of the nicols, as Dippel (1998) observed in other gymnospermous tracheids. The radial section of the tangential wall of the tracheids looks bright, while the surface of the radial wall, with the exception of the pits, is generally dark. When the gypsum plate (red I) is inserted between the object and the analyser, with its $\mathfrak{c}$ axis at $+45°$, the first and third quadrants of each pit are bright yellow, and the second and fourth quadrants blue, while the section of the wall varies from blue to green, and the surface of the wall is colored variously. Therefore, in the longitudinal section of the tracheidal wall the optical elasticity in the direction parallel to the surface of the wall, is less than that perpendicular to the surface. Further, when a longitudinal section of thick-walled summer tracheids of a coniferous wood, e.g. the wood of Sequoia, is observed between crossed nicols, on inserting the gypsum plate (red I) in the usual direction and putting the longitudinal axis of the tracheids parallel to the vibration direction of the polariser, the color of the section of the wall of the tracheids is blue to yellow. It is blue when the major axis of the orifices of the pits of the cross area of the radial wall is parallel to the $\mathfrak{c}$ axis of the gypsum plate, but it is yellow when the latter is perpendicular to the $\mathfrak{c}$ axis. In this case the orifices are oval, and the major axis is oblique to the longitudinal axis of the tracheids.

Consequently the axis of the least and of the intermediate optical elasticity of the wall of the tracheids is parallel to the surface of the tracheidal wall, and is oblique to the longitudinal axis of the tracheids.

Pl. X, Fig. 10 is a microphoto of the radial section of a fossil wood, possibly a crytomerian wood, in lignite from the Nagakudé colliery in Aichi Prefecture, which was taken under similar conditions as the photograph of Pl. X, Fig. 9. As is seen in Fig. 10, the wall of the bordered pits as well as the wall lamellae of the tracheids in section show the double refraction, just as in the wood of a living conifer described above. The insertion of the gypsum plate (red I) also gives the same effect of interference colors as with the wood of a living conifer.

Thus when a cross section of a tracheidal wall of a living or fossil (lignite) coniferous wood is observed with crossed nicols with the insertion of the gypsum plate in the usual way, the interference color in the first and third quadrants in each section of the cell is yellow, while in the second and fourth quadrants it is blue, therefore the optical elasticity in the direction perpendicular to the surface of the wall is greater than in any direction parallel to the surface of the wall. Consequently the axis of greatest elasticity is perpendicular to the tracheidal wall. In other words, the maximum axis of the indicatrix or the axis of least elasticity is parallel to the surface of the wall slightly oblique to the longitudinal axis of the tracheids, the intermediate axis also being parallel to the surface of the wall but perpendicular to the maximum axis, and the minimum axis of the indicatrix or the axis of the greatest elasticity is perpendicular to the wall surface.

Pl. X, Fig. 11 is a microphoto of a cross section of another wood in lignite from a seam near Sendai, in Miyagi Prefecture. The spring wood of the specimen was much compressed so that the details of the wood could hardly be made out; but some of the tracheids in the summer wood were white, and the others dark brown under the microscope. This difference in color came out very sharply in the photograph.

Pl. X, Fig. 12 is a microphoto of a part of the same section highly magnified, and taken with crossed nicols. It is remarkable that the cell wall which was white under the normal light in Fig. 11 shows double refraction, and its primary lamella shows much stronger double refraction than the secondary and tertiary, while the cell wall which was dark colored in Fig. 11 does not show the anisotropic character at all in its secondary lamella, though it may be retained in the primary lamella.

We add here that when the secondary lamella loses its anisotropic character, the tertiary lamella generally suffers a similar change. Thus it seems that the alteration in the tracheidal wall begins in the secondary lamella, and proceeds to the inner tertiary and then the outer primary lamella; in other words the ligno- pecto-cellulose lamella undergoes the change earlier than the cellulose lamella, the primary lamella being the most resistant of the three kinds of lamellae in the tracheidal wall. Indeed the primary lamella often retains the property of double refraction even when the alteration of the wall had gone on so far that the inner lamellae had become swollen and the cell cavities had consequently

disappeared, the entire cell wall, except the primary lamella, having become homogeneous (Pl. XI, Fig. 17).

The above statement is also to be supplemented by the following facts: 1) the wall of the tracheids in lignite, even when it still retains the property of double refraction, scarcely shows the reaction of a lignified membrane by the treatment with phloroglucin and strong hydrochloric acid; 2) the cavity of the tracheids in lignite is generally filled with some granular substance. When such a tracheidal cell is treated with a solution of potassium iodide and iodine and strong sulphuric acid (66.6%), the granules as well as the tracheidal cell wall show the cellulose reaction. This substance can be dissolved and removed from the cell cavity by means of ammoniacal cupric oxide. It is thus highly probable that this substance filling the cell cavity of coniferous wood in lignite is of a cellulose nature, and that it was derived in a colloidal state from the cell wall as its disintegration product in the process of coalification and accumulated in the cell cavity; 3) after treatment with the ammoniacal cupric oxide and subsequent washing, the tracheidal wall in lignite can be clearly stained with a solution of ruthenium red, which shows that the remaining wall is of a pectic nature; and the wall retains the property of double refraction, though it becomes weaker after the treatment; 4) the tracheidal cell wall in lignite, which was treated after the method of König and Rump (1914) and thus deprived of its cellulose, and probably of the pectic constituents too, scarcely has the property of double refraction, just as is the case with the lignin-wall which remains after the tracheidal cell wall of a living coniferous wood is subjected to the same treatment.

Thus in the process of coalification the ligno-pecto-cellulose lamella or secondary lamella of coniferous wood in lignite undergoes alteration first, but the cellulose nature is retained in the wall, so long as the secondary and tertiary lamellae still possess the property of double refraction.

Considerably different degrees of change in the optical property of the tracheidal wall are found even in the different parts of one and the same cell. Pl. X, Figs. 13 and 14 show examples which are the microphotos of the same longitudinal section of coniferous wood, the former having been taken under normal light, and the latter under polarized light with crossed nicols. The darker colored parts in Fig. 13 are dark brown and the lighter ones white under the microscope, as in the case of the cross section of a similar kind of wood, shown in Fig. 11. It is

clear from Fig. 14 that the lighter colored parts of the cell in Fig. 13 show double refraction, while the darker parts do not.

In the constituents of bituminous coal the morphological features of the woody tissue are in many cases well preserved, but even in such cases the walls of the tracheids generally do not show double refraction.

The loss of the property of double refraction in the cell wall of woody tissue takes place simultaneously with the loss of cellulose from the cell wall and is a characteristic step in the process of coalification; it is closely associated with the change of color of the cell wall, and also accompanied by chemical changes.

Frey (1926) agreed with Herzog's opinion that the lignin is embedded amorphously in the wall and said: "Der röntgenographische Befund wird durch den optischen sehr schön bestätigt: laugt man dünne Schnitte von Kieferholz etwa einen Monat lang täglich mit frischen Schweizerreagens aus, so gelingt es, die anisotropen Zellulose-mizelle völlig herauszulösen. Die Schnitte, die mikroskopisch alle Einzelheiten wie behofte Tüpfel und dergl. noch deutlich erkennen lassen sind völlig isotrop geworden!"

This statement supports the writer's view concerning the process of coalification, i.e. that the cellulose is gradually lost, and the tracheidal wall becomes isotropic. In Frey's statement his primary lamella is isotropic, while the writer finds that the primary lamella is anisotropic. There is seemingly a discrepancy. This is however due to difference of nomenclature, Frey calling the middle lamella (calcium pectate membrane) the primary membrane, while the writer excludes the latter from the primary membrane. It may be added here that the pectic substance of the primary wall is certainly different from that of the middle lamella at least in its physical or micellar structure, the former being anisotropic, while the latter is isotropic.

The coniferous wood in Japanese coal consists of spring and summer wood like the coniferous wood of the present day. Due to the weakness of the tissue the spring wood generally suffered much even in cases in which the thick walled cells of summer wood still retain their natural shape. Pl. IX, Fig. 5 shows this difference very clearly. The darker stripes show the structure of ray tissue. The zigzag shape in the spring wood shows how the compression occurs. Pl. IX, Fig. 6 is a microphoto from another specimen in which the spring wood is more heavily compressed, so that the details in the wood can hardly be made out. Pl. IX, Figs. 7 and 8 are microphotos of two specimens of still more compressed wood.

The compression of tissue above referred to is, however, by no means limited to spring wood. More generally summer wood, too, is crushed and the regular arrangement of its tissue elements is destroyed. Yet in the former case, the characteristic pits of the tracheids can often be recognized.

Pl. IX, Fig. 8, which is a microphoto of a section of a coniferous wood in lignite from the Mukoyama seam in Miyagi Prefecture, shows an example of heavily compressed wood. Here the annual rings show a wavy appearance due to heavy compression, and almost no cellular structure is to be seen in the spring wood, except the resin cells (r) which appear as black spots scattered in the wood.

Pl. XI, Fig. 15 is a microphoto of a cross section of a coniferous wood in lignite from the Séto seam in Aichi Prefecture. In this figure the black stripes show resinous ray tissue which is very wavy in the compressed part, that is in the spring wood. In this specimen the cell boundaries of the tracheidal tissue can be recognized by the primary lamella of the wall of each cell, which is the only remaining part of the wall, all the other parts of the wall having undergone alteration and become homogeneous (Pl. XI, Figs. 16, 17).

Pl. XVII, Figs. 56–58 are microphotos of sections of a coniferous wood in Jurassic bituminous coal from South Manchuria. The color of the entire tissue under the microscope is dark brown and the cell wall does not show the phenomenon of double refraction under polarized light, but the tissue presents no signs of heavy compression; the bordered pits are clearly recognizable in both the tangential and the radial walls of the tracheids.

In Pl. XI, Fig. 18, which is a microphoto of a section of a piece of coal from the Nagakura colliery, cut vertically to the bedding plane of the seam, can be recognized a tracheidal tissue. Pl. XI, Fig. 20 is a microphoto of a section of a piece of coal from the upper part of the same seam. This is a coniferous wood which is very much altered as in the case of Fig. 15. Pl. XI, Fig. 19 is another specimen of a coniferous wood in bituminous coal. In this section most of the tracheidal cells and ray cells are so much altered as to appear homogeneous, while some tracheidal cells and especially the resin cells retain their cavities.

Pl. XIV, Fig. 45 is a microphoto of a section, cut parallel to the bedding plane, of a piece of Mesozoic bituminous coal from the Ominé colliery. This is a tangential section of a coniferous wood in which

parenchymatous ray cells can be recognized in two places, though the walls of the tracheidal cells show considerable alterations.

When various degrees of the preservation of woody tissue in bituminous coal, lignite, and brown coal are compared, the alteration in the color and other optical properties, mostly due to the separation of cellulose from the cell wall and to alteration in the micellar structure of the cell wall, is more advanced in bituminous coal than in the younger coal, while the state of the alteration of the morphological structure of the cell walls and tissue varies in both kinds of coal.

MÄULE'S REACTION OF LIGNIN. MÄULE (1901) proposed a reagent for testing the lignified membrane. GENEAU DE LAMARLIÈRE (1903) having studied that reaction carefully, states in his paper : " Toutes les membranes lignifiées des Angiospermes qui ont été examinées jusqu'à ce jour présentent nettement la réaction de MÄULE, même lorsque la lignification s'étend à une portion tout-à-fait infime de la paroi...... Chez les Gymnospermes et les Cryptogames vasculaires, ainsi que je l'ai déjà dit, la réaction de la phloroglucine est très intense, bien qu'on obtienne difficilement la réaction de MÄULE chez ces végétaux. Mais chez les Muscinées qui ne montrent jamais de traces de lignin, on n'obtient pas non plus de réaction colorée à la suite de l'action du permanganate."

R. POTONIÉ (1920) refers to MÄULE's reaction emphatically as the only known method for testing the lignified material in coal.

The writer studied MÄULE's reaction on the several materials at hand and will now give the results which she obtained. The following plants were used for the test:

ANGIOSPERMAE

1. *Acer palmatum*, THUNB. (ACERAC.)
2. *Alnus incana*, WILD var. *hirsuta*, SPACH. (BETULAC.)
3. *Clintonia udensis*, TRAUTV. et MEY. (LILIAC.)
4. *Cornus controversa*, HEMSL. (CORNAC.)
5. *Drimys* sp. (MAGNOLIAC.)
6. *Fatsia japonica*, DECNE et PLANCH. (ARALIAC.)
7. *Ficus Carica*, L. (MORAC.)
8. *Ligustrum Ibota*, SIEB. (OLEAC.)
9. *Lilium Hansoni*, BAK. (LILIAC.)
10. *Liriodendron tulipifera*, L. (MAGNOLIAC.)
11. *Morus alba*, L. var. *Tokwa*, BUREAU. (MORAC.)
12. *Poncirus trifoliata*, RAFIN. (RUTAC.)
13. *Prunus donarium*, SIEB. subsp. *elegans*, KOIZ. var. *glabra*, KOIZ. (ROSAC.)

14. *Punica Granatum*, L. (PUNICAC.)
15. *Rosa* sp. (ROSAC.)
16. *Sasa paniculata*, MAK. et SHIBATA (GRAMIN.)
17. *Serissa foetida*, COM. (RUBIAC.)
18. *Thea japonica*, NOIS. (THEAC.)
19. *Zea Mays*, L. (GRAMIN.)

GYMNOSPERMAE

GINKGOALES

1. *Ginkgo biloba*, L. (GINKGOAC.)

Coniferae

1. *Chamaecyparis obtusa*, S. et Z. (CUPRESSAC.)
2. *Ch. obtusa*, var. *pendula*, MAST. (,,)
3. *Ch. pisifera*, ENDL. (,,)
4. *Ch. pisifera*, ENDL. var. *squarrosa*, MAST. (,,)
5. *Ch. pisifera*, ENDL. var. *filifera*, MAST. (,,)
6. *Juniperus chinensis*, L. (,,)
7. *J. chinensis*, L. var. *procumbens*, ENDL. (,,)
8. *Thuja japonica*, MAXIM. (,,)
9. *Thuja orientalis*, L. (,,)
10. *Thuja orientalis*, L. var. *pendula*, PARL. (,,)
11. *Cryptomeria japonica*, DON (TAXODIAC.)
12. *C. japonica*, DON. var. *torta*, MAXIM. (,,)
13. *Cunninghamia lanceolata*, LAMB. (,,)
14. *Taxodium distichum*, RICH. (,,)
15. *Sequoia sempervirens*, ENDL. (,,)
16. *Abies Veitchii*, LINDL. (PINAC.)
17. *Cedrus Libani*, BARR. var. *Deodara*, HOOK. (,,)
18. *Larix leptolepis*, GORD. (,,)
19. *Picea hondoensis*, MAYR (,,)
20. *Pinus densiflora*, S. et Z. (,,)
21. *P. luchuensis*, MAYR (,,)
22. *P. parviflora*, S. et Z. (,,)
23. *P. pentaphylla*, MAYR (,,)
24. *P. Thunbergii*, PARL. (,,)
25. *P. strobus*, L. (,,)
26. *P.* sp. (,,)
27. *P.* sp. (,,)
28. *P.* sp. (,,)
29. *P.* sp. (,,)
30. *Tsuga diversifolia*, MAXIM. (,,)

32. *Araucaria* sp. (ARAUCARIAC.)
33. *Araucaria excelsa*, R. BR. („)

PTERIDOPHYTA

FILICALES

1. *Pteris semipinnata*, L. var. *dispar*, (KZE.) BAK. (POLYPODIAC.)
2. *Polypodium ensatum*, TH. („)
3. *Osmunda cinnamomea*, L. (OSMUNDAC.)

MUSCINAE

1. *Polytrichum commune*, L. (POLYTRICHAC.)

The lignified tissue or cell wall in all coniferous and fern plants in the above list shows the reddish brown color in different shades, but not red or pink when treated with MÄULE's reagent, as GÉNEAU DE LAMERLIÈRE reported of other conifers and ferns.

The epidermis and sclerotic tissue in cross sections of a stem of *Polytrichum commune* tinged with red, so that the yellow brown color of the wall becomes reddish brown, not as in GÉNEAU DE LAMERLIÈRE's statement on the reaction of the cell wall of mosses.

The lignified cell wall in the tissue of the angiospermous plants mentioned above becomes a very fresh pink or red upon treatment with MÄULE's reagent. The reaction of the lignified tissue of a section of the stem of *Liriodendron tulipifera*, which had been previously treated with hydrofluoric acid to remove the mineral matter in the cell wall, and embedded in celloidin, was just the same as that which had not been so treated. KÜRSCHNER (1925) studied the lignin derived from *Picea excelsa*, and summarizing the results states: "…, so sprechen für das Auftreten eines aggregierten, kolloiden Koniferinkomplexes als Hauptkörper des Lignins, an welchen freies Koniferin zum Teil adsorbiert ist, folgende Gründe : 1. ……. 2. Die gleichartig erfolgenden Reaktionen von Lignin und Koniferin bei der Behandlung nach MÄULE. 3. …… ." If this is correct for all the lignin derived from coniferous wood, the difference of the reactions of the lignified cell wall in the angiospermous plants with MÄULE's reagent from that of the coniferous wood may suggest that the substances which cause the lignification in the two kinds of wood may be different.

The reaction of a Jurassic coniferous wood from the Sha-ho-tzu colliery in South Manchuria, which was the oldest of the materials on which the writer tested MÄULE's reaction, was very feeble ; when it was put into 1% potassium permanganate the color of the tracheidal cell wall was reddish brown; then the material was washed with water and treated with hydrochloric acid and ammonia, when the color turned paler than that of the wall which had not been treated in any way.

The cell wall of angiospermous wood in lignite from Nagano Prefecture showed the typical lignin reaction of the cell wall of angiospermous wood on treatment with MÄULE's reagent, though the red color was not so deep as that obtained with living plants, but it was not at all brown like those of coniferous wood. Therefore MÄULE's reaction of the lignified cell wall is useful for determining whether a wood is coniferous or angiospermous in lignite as well as in the living plants, so far as the writer's observations extend. The thick wall of cortical tissue of mosses in lignite showed the reaction very faintly, though the color was pinkish and not brownish as in the coniferous wood.

b. CUTICLE AND CUTINIZED WALL

Cutin, the characteristic constituent of the cutinized cell wall, is a mixture of fatty substances, and is strongly resistant to chemical agents, such as sulphuric acid, nitric acid, and strong alkali solutions. Consequently after the decay of the other tissues and the innermost layer of epidermal cell wall, the outer cutinized layer of epidermal cell wall together with the cuticle layer is generally well preserved, and the protruding preserved edges of the cutinized wall present the serrate appearance already described by ZEILLER (1882) in Palaeozoic *Bothrodendron* from Tovarkovo, and also by later authors in coal from several localities and strata. Even the chemical reactions of such fossil cuticle and cutinized membrane approach those of living plants, as was first demonstrated by BERTRAND (RENAULT, 1895) in the case of *Bothrodendron*-epidermis.

Japanese lignite, brown coal, and bituminous coal from all the localities from which the materials for this investigation have been obtained also contained their remains. Pl. XII, Fig. 23 shows an example. It is a microphoto of a section of coal from the Nagakura colliery cut at right angles to the bedding plane of the seam. Several white lines lying across the figure represent the sections of cuticle and cutinized walls of the epidermal cell, which are light yellow in color under the microscope. The several parallel layers of such epidermal tissue which lay in contact with each other may be looked upon as remains of leaves piled up in this place, as they are associated with leaves whose tissue is preserved. The black parts between the cuticle layers are the mesophyll of leaves which have coalificated. When they were cut parallel to the surface of the leaves, we got the section shown in Pl. IX, Fig. 3 in which the parenchymatous mesophyll appears with intervening veinlets. Pl. XIV, Fig. 39 shows a part of Fig. 23 highly magnified.

As the outermost layer of the spore membrane of pteridophytes and of phanerogamous plants is cutinized, they are as strongly resistant as the epidermal cell wall. So it is natural that almost all of the investigators, (inclusive of Balfour 1854), of coal have reported the presence of spores in it. In special cases, e. g. in cannel coal, the spore is an important constitutional element, as was pointed out by JEFFREY in 1909, and followed by later authors.

As has already been reported by several authors, e. g. AMBRONN (1888), DIPPEL (1898), YASUI (1925), FREY (1926), the cuticle and cutinized cell wall in living plants show the phenomenon of double refraction like the wall of the cork cell. The maximum axis of the indicatrix is perpendicular to the surface of the cell wall and the minimum axis parallel to the latter.

Curiously enough, this cuticle and the cutinized walls in the present specimen show the phenomenon of double refraction not so strongly as the wall of the well preserved tracheid does, though the morphological appearance gives no indication of alterations which a tracheidal cell wall shows under the microscope.

c. THE SUBERIZED WALL AND CORK TISSUE

So far as known to the writer, there are only a few reports on the suberized cell wall and cork tissue in coal, notwithstanding the fact that they constitute one of the most resistant structures of the plant body and are indeed far more resistant than the lignified woody elements which constitute an important bulk of most coals. STOPES and WHEELER emphasized that the cork tissue must be an important constituent of coal, and demonstrated with figures from a lignite from Dillenberg. In our coal they occur rather frequently not only in lignite but also in bituminous coal. They appear generally as fragments of cork tissue, but sometimes as a part of the bark of a twig.

Pl. XII, Fig. 26 is a microphoto of a section of brown coal containing cork tissue. This coal came from the Hazama seam, Mié Prefecture, which is not worked now, and belongs to a high grade brown coal. In the middle part of the figure the stripes of the cork tissue are shown, somewhat waved and folded at the right side of the figure. Pl. XII, Fig. 27 shows a part of Fig. 26 more highly magnified, and the characteristic features of cork tissue are fully manifested. Pl. XII, Fig. 28 is another microphoto of a section of cork tissue in a brown coal from the Hirako colliery. Here a tangential section of a cork tissue is shown.

Twigs with cork tissue in position were found in coal from several localities. Pl. XII, Fig. 29 shows an example. This figure is the microphoto of a piece of coal from the Ibaraki colliery, and (c) is a part of a cross section of a piece of wood, which is pale brown under the microscope. Surrounding the wood there is a tissue much decayed, and outside of this tissue there is another tissue which is dark brown under the microscope and black in the photograph. Outside the latter a pale colored tissue is seen. In these tissues the arrangement of cells can be recognized. In Pl. XII, Fig. 30, a portion of cork tissue in Fig. 29 is shown with a higher magnification. The dark region across the middle of the figure represents the cork tissue, in which the characteristic regular arrangement of cells is clearly seen. In this specimen the cork cells underwent alteration, and the cell cavity is occupied with certain substances which are possibly derivatives of the substances which composed the wall. Pl. XII, Fig. 24 is the microphoto of a section of a piece of bituminous coal from the Nagakura colliery. In this the structure of the cork tissue is faintly visible. Pl. XII, Fig. 25 shows a part of the cork tissue in Fig. 24 under a higher magnification.

As has been already stated, the suberized wall of cork cells shows the phenomenon of double refraction; the maximum axis of the indicatrix is perpendicular to the plane of the surface of the wall and the minimum axis parallel to the surface of the wall.

A thin section of a cork cell in coal and lignite is bright yellow when well preserved, but generally it is dark brown under the microscope. The bright yellow wall of a cork cell in lignite shows the phenomenon of double refraction as in the wall of the cork cells of living tissue, so that if the gypsum plate (red I) is inserted as usual, the interference color of the section of the wall the surface of which is perpendicular to the c axis of the gypsum plate is indigo blue (an addition-color) and the section of the wall the surface of which is at right angles to the former is orange yellow (a subtraction-color).

Observations of a large number of specimens of cork tissue show that the property of double refraction of the wall is lost in most cases of lignite, while it is retained most frequently in tracheids, bast fibers, and stone cells. From this we may infer that the cork tissue loses its optical properties earlier than the latter in the course of coalification, notwithstanding the fact that the cork tissue of living plants is more resistant to acids and alkalies than are the tracheids, bast fibers, and stone cells.

d. Stone cell

Though most authors who have investigated coal from other sources have not described stone cells in coal, they are found well preserved in Japanese lignite, and are mostly derived from coniferous plant.

Pl. XIII, Fig. 34 shows a part of a fossil including the pith. This material came from the Kashū colliery on Awaji Island in Hyōgo Prefecture. The several large white thick-walled cells are stone cells in the pith of the twig.

Pl. XIII, Fig. 35 shows a radial longitudinal section of the same twig, but in a lower magnification. Another radial longitudinal section through the pith of a twig from the Hirako colliery in Shiga Prefecture, is shown in Pl. XIII, Fig. 36. The white squarish cells somewhat irregularly grouped in the figure are the stone cells of the pith, and in the black parts among them ordinary parenchymatous cells, somewhat decayed and compressed, may be recognized when carefully observed. Pl. XIII, Fig. 37 is a microphoto of a longitudinal section of the pith of a living Cryptomerian twig. Comparing these figures, we see that the stone cells as well as the parenchymatous tissue in the pith of the above mentioned fossil twigs resemble very closely those of the living Cryptomeria in size, shape, nature of cell wall, and the topographical distribution of tissues.

In Pl. XIV, Fig. 41, which is a microphoto of a part of a longitudinal section of a small twig in lignite from the Kashū colliery, stone cells (s) in the ray tissue in the bast are shown. In Pl. XIII, Fig. 42, stone cells (s) are shown from the corresponding tissue of a living Cryptomerian twig.

Pl. XIII, Fig. 31 is a microphoto of a part of a young twig in lignite from Tayama, Kyōto Prefecture. The stone cells (s) in the cortex are well preserved. Pl. XIII, Fig. 32 shows the cells highly magnified. These sections of stone cells in lignite, so far as the writer's observations go, are generally white but sometimes yellow under the microscope, and show the phenomenon of double refraction. The minimum axis of the indicatrix of the wall is perpendicular to the surface of the cell wall, and the other two axes are parallel to the tangential plane of the cell wall and perpendicular to each other, as in these walls in tracheids or bast fibers.

The property of double refraction is here retained remarkably better than in the tracheids and bast fibers, in other words the stone cell is better preserved. From this we are probably justified in assuming

that the stone cells are well preserved in bituminous coal too, although due to their scarse distribution among parenchymatous cells they may escape recognition as such.

e. Bast fiber

The cell wall of bast fibers is mostly lignified and is resistant to the several reagents and natural agencies, so that they are frequently found well preserved in our coal, although most coal investigators seem not to have recognized them as tissue in coal.

Pl. XVI, Fig. 51 is a microphoto of a section of a twig in lignite from the Nagakudé colliery in Aichi Prefecture. Because of compression in the fossil the section was cut somewhat oblique, so that the fibers show transversal as well as longitudinal sections. In the longitudinal section the cell cavity appears as a dark line in the figure. Parenchymatous cells and the sieve tubes are located in the dark region in the photograph. The bast fibers are of a pale yellow color and the parenchymatous cells dark brown under the microscope.

The white striped darker part at the left side of Pl. XIII, Fig. 38 represents the bast in the twig, and the elongated stripes are longitudinal sections of the fibers.

Pl. XIV, Fig. 43 is a microphoto of a cross section of a twig with the bark in which bast fibers are well preserved. The specimen came from the Tayama colliery in Kyōto Prefecture. The lighter colored part is the wood, and in the darker outer part cross sections of the compressed bast fibers appear as small lighter colored bars. Pl. XIV, Fig. 44 shows a part of the latter under a higher magnification. The cross section of one of the bast fibers (f) appears clearly.

A thin section of a well preserved bast fiber in lignite is usually either white or yellow under the microscope, but sometimes brown. Such a difference in color may be met with even in different parts of one and the same fiber.

As in the tracheids, the phenomenon of double refraction is also observed in bast fibers of living conifers, and the optical orientation is also the same. The maximum axis of the indicatrix is parallel to the surface of the fiber, the minimum axis being perpendicular to the surface of the wall.

The property of double refraction is well preserved in the white or yellow fossil fiber. When the longitudinal section of a fiber is observed under the microscope between crossed nicols, inserting the gypsum plate (red I) in the usual way, the wall the surface of which lies

parallel to the c axis of the gypsum plate shows an addition-color, while the wall the surface of which is perpendicular to the c axis shows a subtraction-color, as in the case of tracheids of both fossil and living conifers. Like the brown tracheids, brown bast fibers do not show the phenomenon of double refraction. The only noticeable difference between tracheids and bast fibers is that the bast fiber in the lignite shows no very clear distinction of the three kinds of thickening in the lamellae of the wall, so that characteristic differences in the optical behavior of different lamellae of the wall such as are described in the case of tracheids are not observed in fossil bast fibers.

Bast fibers are present not only in lignite, but also in our bituminous coal, though generally not in such a good condition as in the former. Bast fibers do not occur in large masses as do the tracheidal cells. It is quite natural that they should appear scattered in small groups in coal, as they are usually isolated in the parenchymatous tissue.

f. Sieve tube

In the matrix in coal, the sieve tube is not easily recognizable, but its fragments showing sieve areas of the lateral wall in perfect condition appear in the fusaine from the Aichi and Sendai districts. Their color under the microscope is generally deep brown. The mode of distribution of the sieve areas on the cell wall, and their shape and size show that they belong to either certain gymnospermous or lower angiospermous plants.

g. Parenchymatous cell wall

The wall of the parenchymatous cell generally consists of pectin and cellulose, except when the wall is altered, e. g. lignified.

Text Fig. 1. Cross section of a part of a leaf in coal from Kankan seam in the Méo colliery. ×750.

Pl. XIV, Fig. 40, (b) which is a microphoto of a piece of coal from the Kankan seam in the Méo colliery, shows a good example of a well preserved parenchymatous cell wall in bituminous coal. The bright portion in this figure is a cross section of a leaf. The uppermost layer of the latter is the epidermis of the leaf and the rest the parenchymatous tissue, probably palisade and some spongy tissue.

In the Text Fig. 1 a part of the epidermal tissue and the adjoining parenchymatous cells of the leaf in Fig. 40, (b) are shown in a higher magnification. The shaded region in Text Fig. 1 represents epidermal cells, and the rest the parenchymatous cells. The blank portion of the outer wall of epidermal cells shows the cuticle including the cutinized lamellae of the cell wall. These lamellae are bright yellow under the microscope. The inside black portion of the wall of the epidermal cells represents the noncutinized cellulose lamella of the wall. The latter, together with the lateral and basal cell-wall of epidermal cells, and the cell wall of other parenchymatous cells are brown, but they nicely retain the morphological structure.

The parenchymatous cell wall in general, as the writer has already shown (1925), shows the phenomenon of double refraction and with the insertion of the gypsum plate (red I) the interference color of the wall which is parallel to the **c** axis of the gypsum plate is blue (an addition-color), and that of the wall which is perpendicular to the latter is orange yellow (a subtraction-color). Therefore the axis of the smaller elasticity of the cell wall is parallel to the tangential plane of the cell wall, and the axis of the greater elasticity is perpendicular to the latter.

The double refraction in the wall is essentially unchanged after either one of the chemical components, pectin or cellulose, is dissolved out of the wall, though it becomes a little weaker, that is to say, this optical property is due to both of the two components.

The parenchymatous tissue in Japanese lignite and bituminous coal is mostly found in a much compressed condition, but in some cases the state of preservation is so good that it is possible to determine whether it is that of the leaf or bark. A thin section of the wall of such a parenchymatous cell is dark brown under the microscope, and generally does not retain the property of double refraction.

In case a parenchymatous cell wall is lignified, as in ray cells of a well preserved coniferous wood in lignite, the property of double refraction is retained, though generally the wall of the ray cells loses this property earlier than the wall of the tracheids. It may be added here that the parenchymatous cell wall which retains this optical property in lignite presents also the cellulose reaction.

h. Chitinous membrane

Chitin is a strongly resistant substance, only partly soluble in concentrated hydrochloric acid, strong nitric and sulphuric acids, and decomposes when heated in a very concentrated acid and strong alkali

solution. The cell membrane of most fungi is known to contain chitin. Consequently the fungal cell wall is also resistant to external agencies and is often in a fine state of preservation. The color of the fungus tissue in coal is generally deep brown. Pl. XIX, Figs. 75 and 77 are microphotos of a section of angiospermous wood from a lignite specimen from Nagano Prefecture. The wavy black lines running lengthwise and crosswise show the hyphae of a certain fungus. The thick oblong or rodlike black bodies in the figures are the conidia grown on the hyphae. Each conidium consists of a row of cells, with septa between them (Fig. 75). These conidia, as far as the cell wall is concerned, are not in the least damaged or deformed and any observer would feel as if he were dealing with a living fungus, though the cells of the host are much compressed and broken, so that in some parts the cellular structure is scarcely preserved. Pl. XXIV, Fig. 117, (a) and (b) show the microphotos of a mass of fungal hyphae and conidia in a piece of bituminous coal from the Miiké colliery. Of several other figures, 111, 113, 114, the material from Nagakudé, 112 that from Ominé, 118 from Otsuji, and 121 from Takaé, show also the remains of fungi.

IV. Bright coal, dull coal, and fusaine

The heterogenous texture of coal observed on the surface of a block of coal which is perpendicular to the bedding plane of the seam, had already attracted the attention of Karsten in 1826. He distinguished the two parts in coal, the dull soft-looking and the bright deep black stony part, the former being the continuous matrix-like part, while the latter is the discontinuous, or we may say, embedded part. Since then these two constituent parts of coal have been investigated by several authors. Among them Thiessen (1920) studied the American bituminous coal and classified its two components as mother of coal and compact coal; he further distinguished in the compact coal two parts, the dull coal and the bright coal, and gave the name Anthroxylon to the material of woody nature in compact coal. The composition of Japanese coal is quite the same as that of American bituminous coal.

The charred materials including charred wood in brown coal and lignite correspond to the mother of coal just referred to, the so-called matrix to the dull coal, and the 'lignitoid' of Jeffrey to the bright coal in bituminous coal. The essential difference in the corresponding parts of bituminous coal and of brown coal and lignite lies in the degree of their coalification.

A. Bright coal, anthroxylon

The bright coal among the constituents of coal from several parts of Japan and some localities in China consists mostly of coniferous wood, but partly of angiospermous wood.

B. Dull coal

The constituents of dull coal in Japanese coal which were examined are fragments of woody tissue, young shoots, leaves and their fragments, fungal hyphae and fructifications, spores and pollen grains, fragments of the periderm and bast, &c. As to the bark, Thiessen (1913) states in his reports: "It can be said with certainty that the bark has contributed no appreciable amount to coal, nothing has been met with certainty as derived from bark". Stopes and Wheeler (1918) differed from him and emphasized that the bark should be considered an important constituent of coal. In the Japanese coal that the writer has investigated, however, the bark or periderm tissue was frequently met with, and the latter will be recognized by plant-anatomists with unmistakable certainty (Pl. XII, Figs. 24–30 and Pl. XIV, Figs. 43 and 44).

In the case of Japanese lignite or brown coal, so far as the writer's observations go, some lower plants, e. g. mosses, some algae and their fragments, and in one case a protozoan shell, were found.

C. Fusaine

The different names "mother of coal", "carbonized wood", and mineral charcoal have been used by different authors for the charred substances in bituminous and brown coals and lignite. However, Stopes and Wheeler (1918) proposed that the term "fusain" be used only for the charred material to avoid confusion, and as Jeffrey (1924) proposed the spelling "fusaine", the latter term is adopted here after these authors.

In those cases which the writer has observed the fusaine mostly consists of small friable pieces or fragments of charred materials in disorder. One example is shown in Pl. XV, Fig. 46, which is a photograph of a section parallel to the bedding plane. Such material is generally associated with some larger pieces of wood, some parts of the latter frequently being charred. One such specimen is shown in Pl. XV, Fig. 47, which is a part of a large trunk of a Sequoia-like tree

in lignite from the Kōzōji colliery, in the Aichi coal-field. The trunk was found greatly compressed, and had some clefts in the tissue of the wood. The cut surface of the wood was of a light grayish brown color. The summer wood of the specimen was very thin, generally two or three cells, sometimes one cell thick; the color of a thin section of the tracheids was reddish brown. The spring wood was much crushed, so that the arrangement of the tracheids was difficult to trace, though the cell wall of the latter when observed with crossed nicols was found to have still retained the characteristic physical properties of the wall, while the cell wall of the summer tracheid had not. In several parts of this trunk, such rather well preserved cells were in contact with the charred cells; and the charred tissue lined the clefts.

As to the origin of the fusaine, two views have been proposed: one is that of the burnt wood origin which was suggested first by DAUBRÉE and advocated by JEFFREY, and the other is that of the alteration origin which was already enunciated by ROGERS in 1848 and emphasized later in 1858. He states that "This [mineral] charcoal [fusaine], produced possibly in contact with the atmosphere, and not under water, on the surface of ancient coal-forming bogs, and not within them, has escaped the maceration which converted the rest of the vegetation to a soft pulpy disorganized mass, already freed from the gases associated with it in the tissues of the plants, and reduced to the elemental and unalterable condition of pure carbon, but by a change so gradual and soft as to have retained its original organic structure, has undergone no after-alteration whatever......".

His view was followed by WHITE and THIESSEN (1913) with slight modification.

The heterogeneity of the component materials and their disorderly arrangement, which are just as in the case of dull coal, give the impression, that the material was charred chemically by a slow process in the state in which it is found, and did not accumulate after it had been charred. There seems however to be no reason to doubt the occurrence of mountain fires in the Tertiary, and the burnt wood origin view seems also to be reasonable, because we often see burnt wood in the drifts of the present age.

Thus there may have been two ways in which the charred part of lignite or bituminous coal originated, namely by the drifting of the burnt wood and by the charring of the accumulated material.

V. Flora concerned in the formation of Japanese coal

A. Coniferous wood

The writer has examined in detail the structure of about 50 pieces of what seemed to have been wood, which were contained in lignite and bituminous coal from Japan and South Manchuria. With the exception of two pieces, they consisted of pitted tracheids, wood parenchyma or resin cells, and parenchymatous ray tissue.

The pits of the tracheids were generally round, large and bordered. They occur generally in one or two rows, and in the latter case in horizontal pairs, quite seldom do three pits occur in a horizontal row. As a rule they are distributed upon the radial wall only in the spring tracheids, but upon both the tangential and radial walls in the summer tracheids.

The ray cells are all parenchymatous. Their horizontal wall is rather thick, smooth or slightly pitted, while the terminal wall is thin, smooth, and straight or somewhat curved. Upon the lateral wall pits are prominent. They are in one, two, or sometimes three rows. The pits are smaller and bordered; their orifices are generally oval, though in one case it was rather round. Accordingly the pits of the ray cells are cupressoid.

The ray cells are generally uniseriate, and they are sometimes resinous.

The resin cells or wood parenchyma cells are made prominent by the presence of resinous substance. In longitudinal sections they appear in longitudinal rows, distributed among the tracheids.

Wood having the characteristics above described belongs to conifers.

The generic or specific identification of this type of wood owing to the simplicity and similarity of its structure is most difficult, even in the case of present day plants, unless its bark is well preserved Consequently the quantitative characters, e. g. height of ray cells and that of ray tissues, must be considered for the determination of such wood, but quantitative characters always fluctuate and for this reason some investigators have hesitated to rely upon them. If we adopt the statistical method, however, the uncertainty of this fluctuating character

can be got rid of, especially when other points, such as the age of the wood and the parts or organs of the plants from which the latter is derived, are also considered; for if not one single character, but several characters are considered together they will serve at least to distinguish the different types of xylons, although they may be still insufficient for the specific or generic identification of the individual plant.

In measuring the distribution of ray tissues in any wood I have not made use of the distances between the ray tissues in terms of the number of tracheids between neighboring ray tissues in a cross section of the wood, which has been often made use of in the diagnosis of wood by other authors, for the reason that this distance varies in sections of different thickness, in case a definite thickness is not given. This is especially the case when a low power objective with smaller numerical aperture is used, because such an objective has greater penetration power than one with a larger numerical aperture. So in measuring the distribution of ray tissue, I have used the average number of ray tissues in one sq. mm. in tangential sections. The important specimens of coniferous wood examined are as follows:

a. **Specimen No. 85, Cupressoxylon-type wood,** presumably a Crytomerian twig, Pl. XVI, Figs. 48–52.

This specimen, collected in the Nagakudé colliery in Aichi Prefecture, measures 4×1.8 cm. in diameter and more than 15 cm. in length, and is about 12–13 years old. The color of the wood is brown. The wood, pith, and a part of the bast are well preserved. The cell wall, except that of some parenchymatous cells, retains the characteristic properties of double refraction. Pl. XVI, Fig. 48 is a microphoto of a cross section of the specimen. The upper darker part is the summer wood, and the lower lighter part the spring wood. The transition from the spring wood to summer wood is gradual, as is seen in both Figs. 48 and 49.

The summer wood is rather thick, 20 or more cells thick in the cross section, while the spring wood is almost twice as thick as the summer wood.

The tracheids in rows are rather regular. The tracheidal pits are prominent as shown in Fig. 49. They are, as a rule, arranged in a single row in both summer and spring tracheids. Between the pits the

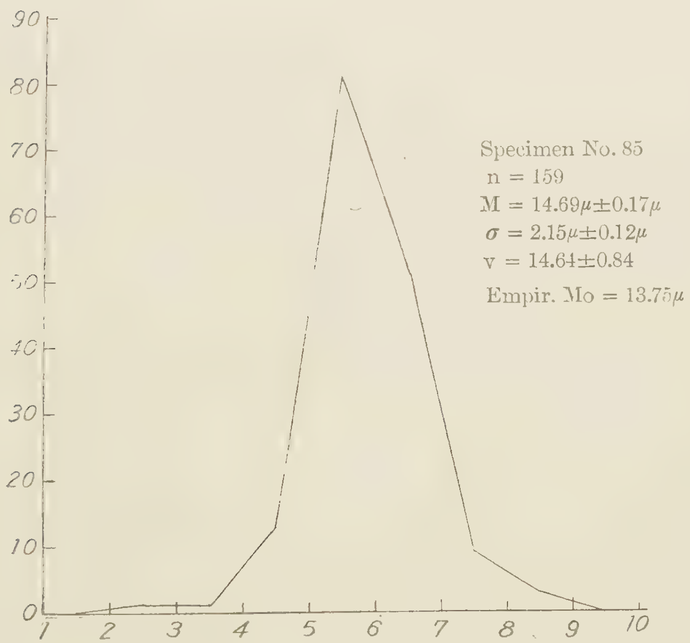
'bars of Sanio' show clearly in the spring tracheids, but faintly in the summer tracheids.

The ray tissue is entirely parenchymatous, some cells being more resinous than others, as shown in Pl. IX, Fig. 1. The cells of the tissue are generally 16 to 20 micra wide and 50 to 100 micra long, and the average number of ray tissues in one sq. mm. of a tangential section of the wood is 173. Table 1 and Text Fig. 2 show the height of ray cells in micra.

Table 1

Class vaule*	2.5	3.5	4.5	5.5	6.5	7.5	8.5
Frequency	1	1	13	81	51	9	3

*Unit of class value=2.5 μ =one division of Leitz step-micrometer (Leitz oc. 2 × Zeiss D).

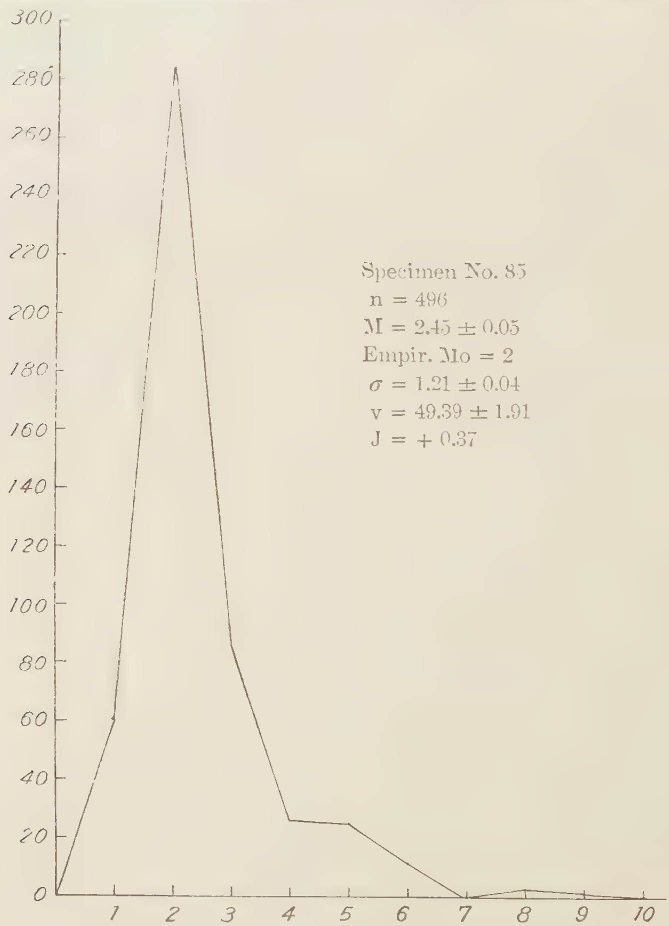


Text Fig. 2. The frequency polygon of the height of ray cells in micra, and its statistical constants.

The frequency curve of the height of ray tissue in terms of the number of cells is a skew curve as is seen in the adjoining graph, and is characterized by the statistical constants given below (Table 2 and Text Fig. 3).

Table 2

Class value in terms of the number of cells of the height of ray tissues	1	2	3	4	5	6	7	8	9
Frequency	60	284	85	26	25	12	0	3	1



Text Fig. 3. The frequency polygon of the height of ray tissues, and its statistical constants.

The horizontal wall of the ray cell is thick and in a few cases pitted, the terminal wall is thin, straight or somewhat curved and not pitted. The pits on the lateral wall are small, bordered, and 1 to 4 of them occur in one or two horizontal rows per cross area. The orifice is oval, elongated horizontally or obliquely.

The wood parenchyma or resin cells in the cross section of the wood are scattered through the spring and summer wood, and are few in number.

The preservation of the pith is not very satisfactory as may be seen in Pl. XVI, Fig. 52, which is a microphoto of a cross section of the part including the pith of the specimen ; still it is recognizable that the pith consists of thick walled parenchymatous cells and large stone cells, whose diameter in the cross section varies from 35 to 45 micra. The large white spot in the middle of the photograph is the space from which was detached a large stone cell, which is shown in another section. Similar pith structure is shown in Pl. XIII, Figs. 33–36. The specimen from which the latter figures were taken came from different localities, namely the Kashyū colliery in Hyōgo Prefecture and the Hirako colliery in Shiga Prefecture. In the upper half of Fig. 33, is a cross section of a compressed young twig showing the first year's growth only, and its pith contains only four conspicuously large stone cells. Another cross section of a twig is shown in the left corner of the lower half of the same figure. This shows a younger stage of the pith, and the stone cell is not yet developed. Fig. 36 is the microphoto of a longitudinal section of the pith. Here as mentioned already in the last chapter, the stone cells are white, while the parenchymatous cells are black. Pl. XIII, Fig. 37 is a microphoto of the longitudinal section of the pith of a living *Cryptomeria*, the magnification being the same as in Fig. 36. This relation of the age of twigs and the state of development of the stone cells in the pith, is precisely what we find in young stems of living *Cryptomeria*.

Pl. XVI, Fig. 51 is a microphoto of the section of the bast of the same twig.

On account of the compression, the sieve tubes can not be clearly located in their ordinary position, although the bast fibers are shown clearly, and other tissues as described in the last chapter can be traced. Pl. XIII, Fig. 38 is a microphoto of the longitudinal section of one and the same twig as that from a section of which the microphoto, Fig. 34, was taken. In this, short stout thick walled cells, the stone cells in bast

which form a topographically characteristic structure in the bast of living cryptomerian twigs, are shown.

Thus the anatomical structure of the present specimen, especially the characteristic pitting of the wall of the tracheid and ray cells, the distribution of the resin cells, and the linear arrangement of the ray tissue, locate the specimen in the Cupressoxylon type of wood. The structures of the pith and the bast point the affinity of this plant to the living *Cryptomeria* and *Cryptomeriopsis mesozoica* among the fossil plants, but whether the plant belongs to a new species or not, could not be determined.

DIAGNOSTIC SUMMARY

Pith. The pith consists of parenchymatous cells and large stone cells, the diameter of which is 35 to 45 micra.

Bast. Sieve tubes alternate with bast fibers, and in the ray tissue in the bast there are some stone cells.

Wood. a. Transverse section. The growth ring well developed, 60 or more tracheids concerned; transition from spring to summer wood gradual, sometimes false rings appear. The summer wood not very prominent as compared with the spring wood. The spring tracheid very 'open', generally squarish. The mean radial diameter of the tracheids is $22.2\,\mu$, the standard deviation being $5.5\,\mu$, so that its coefficient of variation is 24.8; and the average area of a cross section of the tracheids is 238.38 sq. μ. Resin cells rather few in the specimen, and scattered throughout the wood. Resin canal developed neither normally or traumatically. Ray tissue prominent and uniseriate.

b. Radial section. Ray cells straight, some resinous, equal to two to five tracheids; horizontal wall thick without pits, terminal wall thin, generally not pitted, straight or slightly curved; lateral wall with roundish oval narrow bordered pits, 2 to 4 per cross area and generally in two rows; pit-orifices rather narrow and oblique to the axis of the cell. Bordered pits of the tracheid not large, generally in one row, round with round orifices; 'bars of Sanio' present, in summer tracheids obscure. Resin cells uniseriate.

c. Tangential section. Rays all uniseriate; the mean of the height of 496 rays, in terms of the number of cells $=2.45\pm0.05$, $\sigma=1.21\pm0.04$, $\mathrm{v}=49.39\pm1.9$, Empir. $\mathrm{Mo}=2$, $\mathrm{J}=0.37$. The mean of the height of 159 ray cells $=14.69\mu\pm0.17\mu$, $\sigma=2.2\mu\pm0.12\mu$, $\mathrm{v}=14.6\pm0.8$. The average number of the rays in 1 sq. mm. is 173.

Material somewhat coalificated. The specimen is represented by a part of a stem.

Locality: Nagakudé colliery in Aichi Prefecture, Central Japan. Upper Tertiary.

Provisional name: *Cupressoxylon nagakudéense.*

b. Specimen No. 73, Cupressoxylon-type wood, Pl. XVI, Figs. 53–55.

The material was collected in the Ōkusa colliery in Aichi Prefecture; it is rather well preserved. Pl. XVI, Fig. 53 shows a cross section of its wood. The cell wall of the tracheid retains the characteristic double refraction of the lignified cell-membrane.

The annual growth is thin, generally 6 to 7 cells thick, sometimes even thinner. The transition from the spring to the summer wood is abrupt, while in some cases no special summer tracheids are developed at all. In cross sections the resin cells are scattered in the spring and summer wood; ray tissue rather prominent; the tracheids 'open' and squarish. The average area of cross-sections of tracheids is 472 sq. μ.

Fig. 54 shows a radial section of the wood. The pits on the radial wall of the tracheids are large, prominent, and are arranged in one row generally, but in some large tracheids in two opposing rows. The horizontal wall of the ray cell is thick, the terminal wall thin, straight or slightly curved; the pits on the lateral wall are bordered, and per cross area 2 to 6 of them occur, generally in two rows.

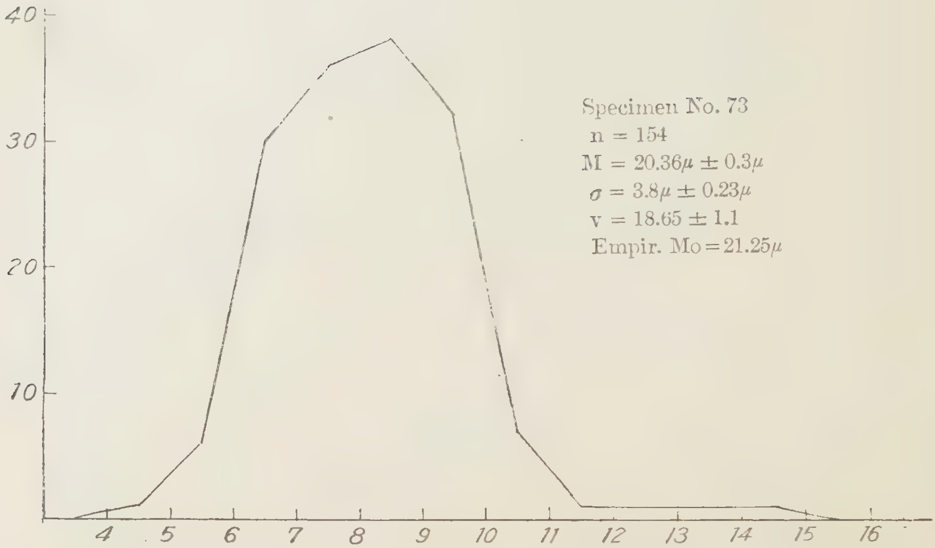
Fig. 55 is the microphoto of a tangential section of the same wood.

Table 3 and Text Fig. 4, the frequency polygon with its statistical constants, show the height of the ray cells in micra.

Table 3

Class value*	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5
Frequency	1	6	30	36	38	32	7	1	1	1	1

*Unit of class value = 2.5 μ = one division of Leitz step-micrometer (Leitz step-micrometer eyepiece × Zeiss D)



Text Fig. 4. The frequency polygon of the height of ray cells in micra in the specimen No. 73, and its statistical constants.

The height of ray tissue in terms of the number of cells is shown in Table 4 and Text Fig. 5, the frequency polygon with its statistical constants.

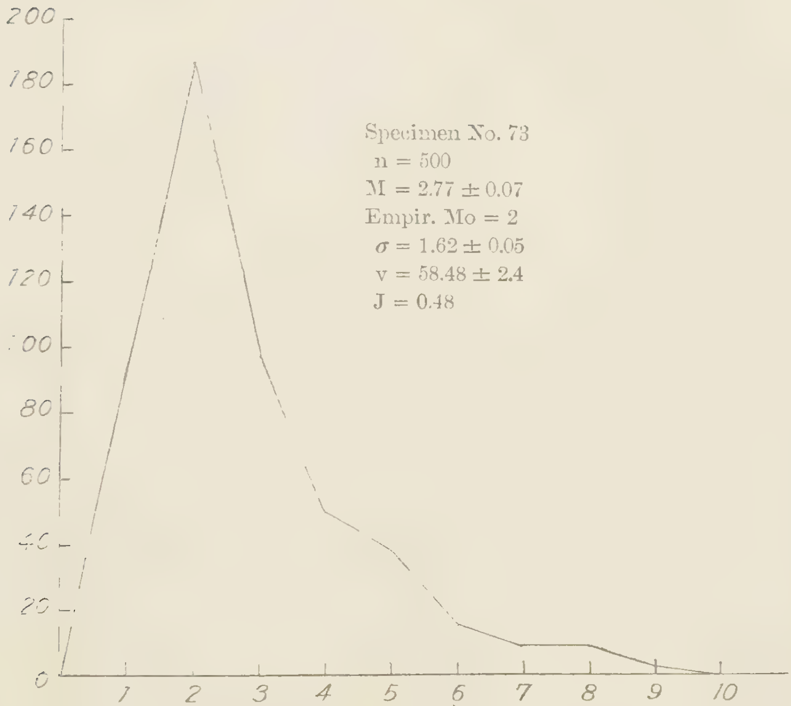
The average number of ray tissues in one sq. mm. is 132.5.

The terminal pits of the summer tracheids are large, rather prominent, and are distributed somewhat irregularly.

The characters above described show that this wood has close affinity with the *Cupressoxylon nagakudéense* but the irregularity in the tissue of the wood and the thinness of the annual ring, together with the slightly larger value of the statistical constants concerning quantitative characters in the former than in the latter indicate its root nature, as will be seen by the comparison of statistical data given in Table 5 concerning the stem and root of *Cryptomeria japonica, 12* years old.

TABLE 4

Class value in terms of the number of cells of the height of ray tissues	1	2	3	4	5	6	7	8	9
Frequency	94	189	98	46	38	15	9	9	2



Text Fig. 5. The frequency polygon of the height of ray tissues in the specimen No. 73, and its statistical constants.

TABLE 5

(The statistical constants of the height of ray tissues in terms of the number of cells, and those of the radial diameter of tracheids in μ, in living cryptomerian wood of 12 years old.)

	Radial diameter of tracheids		Height of ray tissues	
	Root	Stem	Root	Stem
n	171	217	433	341
M	49.55	17.80	2.89	2.67
σ	7.73	5.08	1.88	1.52
v	15.59	28.51	65.05	56.93
J	−0.16	0.8	0.47	0.44

c. Specimen No. 27, Cupressoxylon-type wood, Pl. XVIII, Figs. 64–67.

This specimen came from the Kōzōji colliery in Aichi Prefecture. It was a twig of about 30 years' growth, and measured more than 6 cm. in length and 5×4 cm. in diameter. The preservation was good in the

central part of the specimen, but the outermost part was partially decayed, so that its anatomical details were difficult to trace. The following description is based on the part which was 5 or 6 years old.

Pl. XVIII, Fig. 64 is a microphoto of a transverse section of the specimen. Annual rings well developed, 0.5–1 mm. wide, 37 to 63 tracheids being counted in a year's ring. The transition from spring to summer wood is gradual. The arrangement of tracheids in a cross section is in regular rows, and their walls are rather thick throughout the whole annual growth, which might be due in some degree to the swelling and alteration of the wall in the process of coalification. The summer tracheid in cross section is roundish, but large spring tracheids are somewhat hexagonal. The lamellae of the tracheidal cell wall are seen very clearly. The innermost lamella is of a pale brown color, the secondary lamella is generally brown but the color of its outer part is somewhat lighter, and the primary lamella is whitish. The primary lamella and the outer layer of the secondary lamella only retain the characteristic property of double refraction; in the remaining part of the lamellae of the wall some chemical or physical changes must have occurred, though they show no morphological alteration except in color.

The mean area of a cross section of 165 tracheidal cells is 397 sq. μ.

The cells with their black contents in the photograph are resin cells. They are scattered throughout the spring and summer wood, and on account of the deep brown color of the contents under the microscope are quite prominent among the lighter colored tracheids.

The ray tissue is uniseriate and the cells are resinous. The radial length of the ray cells extends through from two to seven tracheids.

Pl. XVIII, Fig. 65 shows a radial section of the wood. Bordered pits in the radial wall of the tracheid are clearly visible and are generally round, but in some places oval, due to crowded occurrence. Their arrangement is mostly uniseriate, but quite occasionally they appear in opposite pairs. In summer tracheids the pits are often crowded and the 'bars of Sanio' are not sharply represented, though the wood is of the Cupressoxylon type. The terminal pits develop in 5 or 6 layers of summer tracheids.

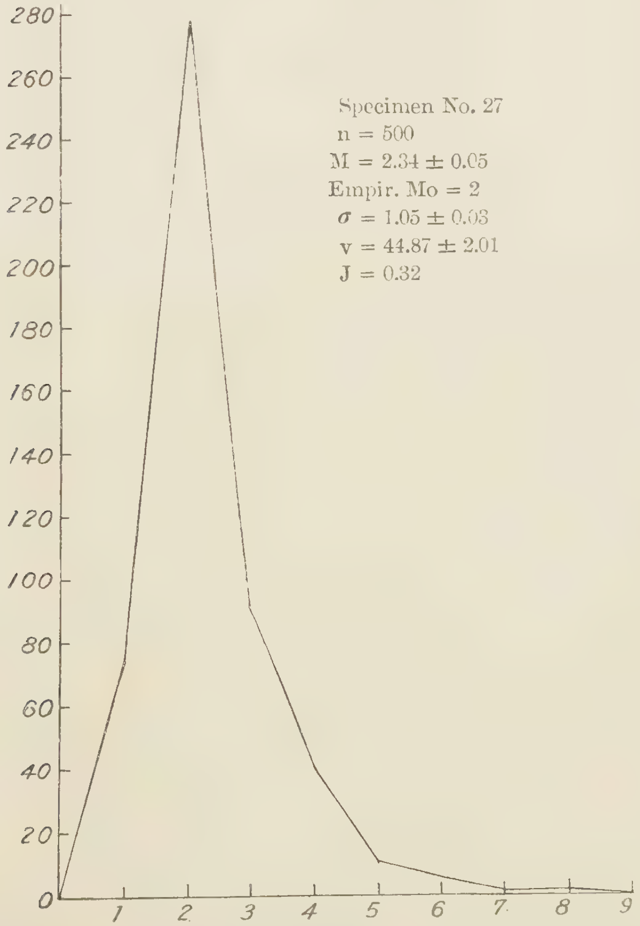
The ray cells are all parenchymatous. Their horizontal wall is thick and pitted, while the terminal wall is thin, slightly curved or even straight, and not pitted. The pits on the lateral wall of the ray cell are rather small, bordered, but very prominent; and the rather narrow orifice is either horizontal or oblique. They occur 2—6 per tracheid,

generally in two, but sometimes in three rows as shown in Pl. XVIII, Figs. 65 and 67.

Pl. XVIII, Fig. 66 is the tangential view of a section of the wood. The terminal pits in the summer tracheid are very prominent. They are small, and arranged compactly. The ray tissue is low, but prominent. The height of ray tissues is shown in Table 6 and Text Fig. 6, the frequency polygon with its statistical constants.

TABLE 6

Class value in terms of the number of cells of the height of ray tissues	1	2	3	4	5	6	7	8
Frequency	74	276	91	40	10	6	1	2



Text Fig. 6. The frequency polygon of the height of ray tissues in the specimen No. 27, with its statistical constants.

The ray cell is mostly round, but sometimes its breadth exceeds the height. The average number of the ray tissues in 1 sq. mm. of the tangential section is 103.

The structure above described shows that the wood is of the Cupressoxylon type, but the size and shape of the ray cells, and the arrangement of the terminal pits in the summer tracheids show some differences from *Cupressoxylon nagakudéense* and living cryptomerian wood.

DIAGNOSTIC SUMMARY

Transverse section. Growth ring well developed, 0,5—1 mm. wide, with 37–63 tracheids in radial thickness of an annual ring; transition from spring to summer wood gradual; spring tracheid 'open', its cross section somewhat hexagonal, average area of the cross sections of tracheids being 397 sq. μ; no resin canal; resin cells prominent, scattered through spring and summer wood; ray tissue sharply defined, uniseriate.

Radial section. Ray cells parenchymatous and somewhat resinous, very prominent, high, all straight; horizontal wall thick, terminal wall thin, somewhat oblique or erect, the pits on the lateral wall small and bordered, orifice narrow and oblique, 2–6 per tracheid and in 2 rows generally, but often in 3 rows; pits on the radial wall of the tracheid are prominent, round, bordered, uniseriate.

Tangential section. Ray tissue uniseriate, broad, very prominent; the mean of the height of 500 rays in terms of the number of cells $=2.34\pm0.05$, $\sigma=1.05\pm0.03$, $v=44.87\pm2.01$, $J=0.32$, Empir. Mo $=2$.

The average number of the rays in 1 sq. mm. is 103.

Material carbonified. The specimen represented by a part of a stem about six years old.

Locality: Kōzōji colliery, Aichi Prefecture, Central Japan. Upper Tertiary.

Provisional name: *Cupressoxylon kōzōjiense.*

d. **Sequoioxylon** NOV. GEN. **hondoense** NOM. NOV., Pl. XVII, Figs. 59–63.

In 1917, the writer described a fossil wood in the lignite from Aichi Prefecture and named it *Sequoia hondoensis.* The original specimen was a small piece of wood very much compressed. Afterwards the writer got several specimens from the same district. Among the latter there was quite a large specimen of similar wood structure. From the

study of these materials the following details may be added to the writer's previous description.

Some of the wood fragments measured about 10 cm. or more in breath and thickness, and 2 or 3 meters in length. They were broken pieces of quite old trunks, though their ages could not be determined. The tissue was compressed, especially that of the thin-walled summer wood, so that the wood was quite hard and could be beautifully polished.

Pl. XVII, Fig. 59 shows a transverse section of the wood in the region of a series of traumatic resin canals. The spring tracheids on account of the thinness of their walls have been greatly compressed, while the summer tracheids due to the greater resistance of their thick walls are largely intact. Nearly all the cell wall in spring wood, notwithstanding such compression, retains its original optical properties as is shown between the crossed nicols; on the contrary some of the summer tracheids which are brown under the microscope have already lost these properties. The growth rings are rather thin, and the transition from spring wood to summer wood is somewhat abrupt. The pits on the tangential wall of summer tracheid show clearly. The resin cells are prominent, and are scattered through the spring and summer wood. The uniseriate rays show clearly, and due to compression appear as wavy lines. Occasionally in the ray cells dark resinous contents may be distinguished, similar to those in the other parenchymatous cells of the wood. Across the middle part of the figure there appears a tangential row of traumatic resin canals, resembling the similar structure in the two living species of *Sequoia*, namely *Sequoia gigantea* and *S. sempervirens*.

Pl. XVII, Fig. 63 shows the traumatic resin canals and the surrounding cellular elements somewhat highly magnified. Pl. XVII, Fig. 60 gives the view of a radial section of the wood under consideration. In the center the abundant parenchymatous cells surrounding the traumatic resin canal can be readily distinguished. Pl. XVII, Fig. 62 shows a radial section of the wood. The pits of the radial walls of the tracheids are usually uniseriate in the summer tracheids, and are frequently biseriate and opposite in the broader tracheids of the spring growth. The orifice of the pit is round or oval in shape. The pits on the lateral walls of ray cells are oval with distinct borders, a feature considered by PENHALLOW to be of diagnostic value for the genus *Sequoia*. The Table 7 and Text Fig. 7, the frequency polygon and statistical constants show the height of the ray tissues of the present wood in comparison

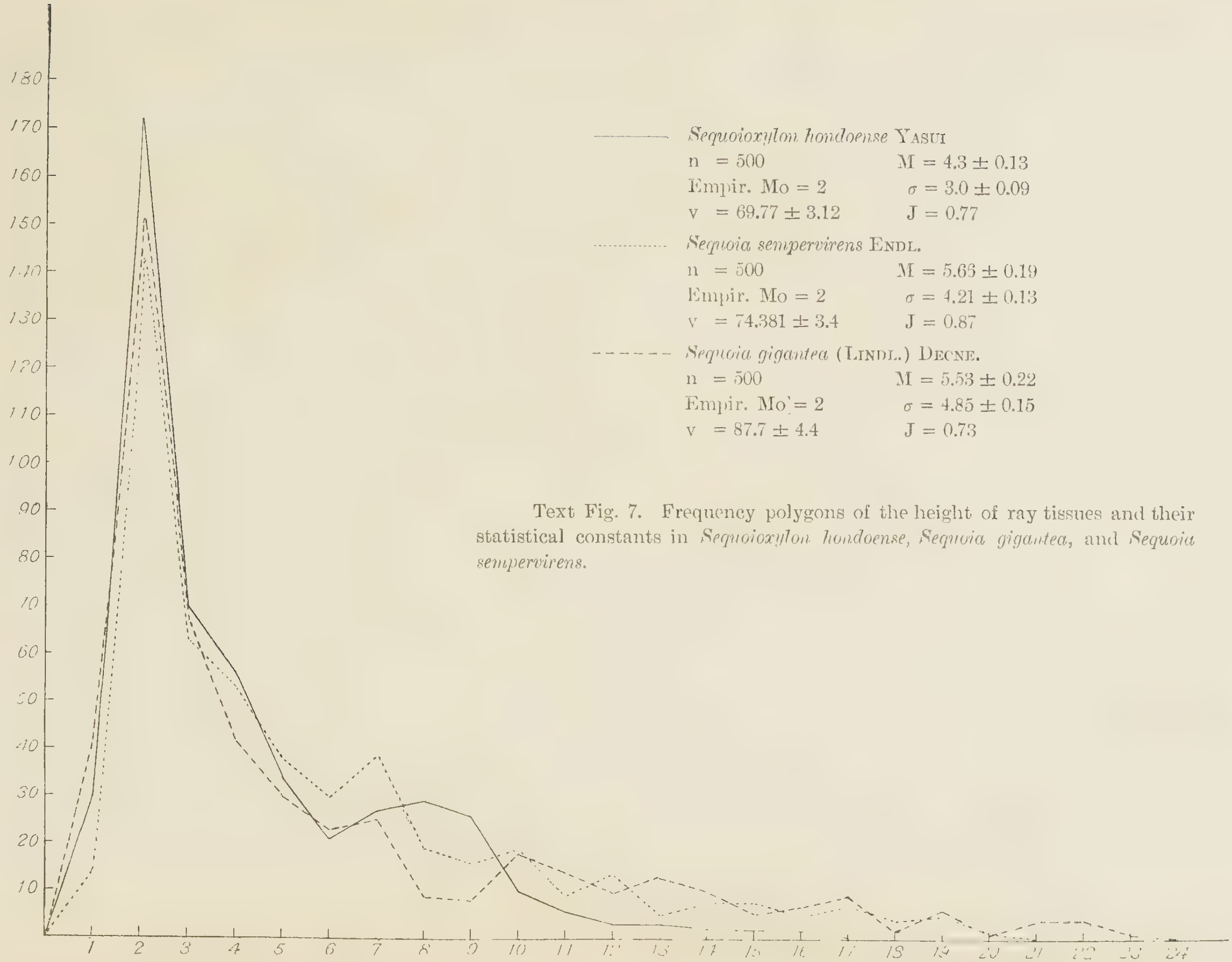
with those of living Sequoias.

TABLE 7

Class value in terms of the number of cells of the height of ray tissues		1	2	3	4	5	6	7	8
Frequency	*Sequoioxylon hondoense*	30	173	70	56	34	21	27	29
	Sequoia gigantea	41	153	68	42	30	21	25	9
	Sequoia sempervirens	14	143	63	53	38	30	39	19

Class value in terms of the number of cells of the height of ray tissues		9	10	11	12	13	14	15	16
Frequency	*Sequoioxylon hondoense*	26	10	6	3	3	2	2	2
	Sequoia gigantea	8	18	14	10	13	10	5	7
	Sequoia sempervirens	16	19	9	14	5	8	8	5

Class value in terms of the number of cells of the height of ray tissues		17	18	19	20	21	22	23	24
Frequency	*Sequoioxylon hondoense*	0	0	0	0	0	0	0	0
	Sequoia gigantea	9	2	5	1	4	4	1	0
	Sequoia sempervirens	7	4	5	1	0	0	0	0



Text Fig. 7. Frequency polygons of the height of ray tissues and their statistical constants in *Sequoioxylon hondoense*, *Sequoia gigantea*, and *Sequoia sempervirens*.

On comparing the height of ray tissues in these three kinds of wood we find that the empirical modes are invariably 2; while a difference is observed between the means as well as the standard deviations in the fossil and the two living Sequoias. This difference of means seems to be real and to distinguish the corresponding species; because the difference ($M_{sempervirens} - M_{hondoense}$) or ($M_{gigantea} - M_{hondoense}$) is larger than $3 \times \sqrt{m^2_{sempervirens} + m^2_{hondoense}}$ or $3 \times \sqrt{m^2_{gigantea} + m^2_{hondoense}}$, namely $1.33 > 3 \times 0.23$ and $1.23 > 3 \times 0.26$.

The structure of our wood as described above — particularly the nature of the pitting of ray cells, the distribution of resin cells, the presence of both the 'bars of Sanio' and traumatic resin canals — points clearly to its close affinity with the living *Sequoia*.

On the bases of the anatomical data, it seems justifiable to place this wood in *Sequoia*, as I did before, because there are no other plant groups which share its characteristics, so far as the living conifers are concerned. However, it may be more adequate not only to call this wood *Sequoioxylon*, instead of *Sequoia*, in view of the fact that the external habit and characters of the plant other than those of its wood are entirely obscure, but also to characterize the wood by the new name *Sequoioxylon hondoense* n. nov. and distinguish it from *Cupressoxylon* and other groups of allied conifers. Moreover, according to Pilger's classification of Coniferae (1926), *Sequoia* on the one hand and *Cupressus* and allied genera on the other belong to the two distinct families, Taxodiaceae and Cupressaceae. Therefore it is not only adequate, but also rather necessary to exclude Sequoian wood from *Cupressoxylon*, in case there are any characters distinguishing the two, which is really the case.

e. **Sequoioxylon miyagiense** sp. nov. Pl. XVIII, Figs. 68–73.

One specimen was collected in the Mukoyama lignite seam, in the vicinity of Sendai, Miyagi Prefecture. Though it was very much compressed, still it was possible to ascertain that it belonged to the same type of wood as a half silicified and half carbonized specimen which was collected under the Koeiji bridge in Sendai. The latter was in a fine state of preservation, so that the following description, based mostly upon the observations made on sections of the latter, applies to both.

The sections were made on one hand by the grinding method, but on the other hand the specimen was first treated with hydrofluoric acid to remove mineral matter, and subsequently the microtome sections were prepared from it. Pl. XVIII, Figs. 68–71 are microphotos of the sections prepared by the grinding method, and Figs. 72 and 73

are those of the sections prepared by the method B.

The main specimen measured about 20 cm. in length, 13 cm. in diameter and 5 cm. in thickness, and was blackish brown in color.

Annual rings average 1-2.5 mm. in thickness, and are very distinct even in the very much compressed condition. The transition from spring wood to summer wood is somewhat abrupt as will be seen in Figs. 68 and 72 which are microphotos of the cross sections of the present wood. The number of tracheids in a year's growth were counted for 30 annual rings, as shown in Table 8. The average ratio of the number of tracheids in spring and summer wood is 100: 61.5.

TABLE 8

Spring wood	31	22	19	20	20	26	16	16	18	15	
Summer wood	14	11	13	11	9	11	10	12	11	8	
Spring wood	6	13	14	9	13	14	9	13	10	10	
Summer wood	3	8	8	4	8	8	4	8	8	5	
Spring wood	12	12	10	14	16	16	16	20	23	9	Total 426
Summer wood	10	10	9	11	9	13	9	15	13	9	262

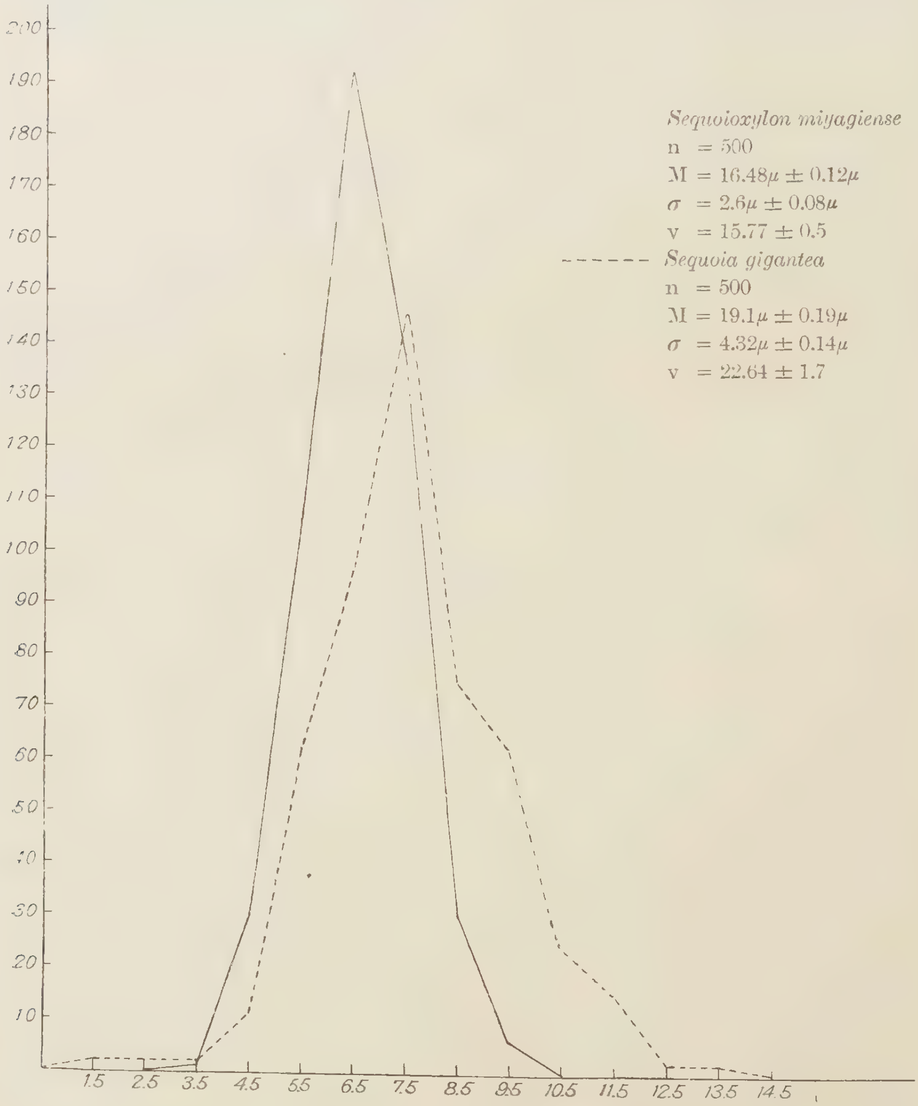
The summer tracheid is thick-walled and the cavities are roundish, while the spring tracheid is thin-walled, 'open', and squarish. The pits are bordered, round, and prominent, and in the spring wood they are found in the radial wall only and are mostly in pairs, but sometimes, there are three in one level. Though the pits are rather compact, the 'bars of Sanio' are clear, while in the summer tracheids the pits on the radial wall are not prominent, probably due to the state of preservation. The terminal pits are, however, very prominent as are shown in Fig. 73. The average area of cross sections of the tracheids is 2254 sq. μ.

The ray tissue is uniseriate and not plentiful, as is shown in Figs. 71 and 73. The ray cells are all parenchymatous, very prominent, though not very resinous. The length of the ray cells corresponds to from two to four tracheids. Table 9 and Text Fig. 8, the frequency polygon with its statistical constants, show the height of ray cells in micra in comparison with those of *Sequoia gigantea*.

TABLE 9

Class value*		1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5
Frequency	*Sequoioxylon miyagiense*	0	0	1	30	106	191	136	30	6	0	0	0	0
	Sequoia gigantea	2	2	2	11	62	96	145	75	62	24	15	2	2

*Unit of class value $= 2.5\ \mu$ = one division of Leitz step-micrometer (Leitz step-micrometer eyepiece × Zeiss D)



Text Fig. 8. Frequency polygons of the height of ray cells in micra and their statistical constants in *Sequoioxylon miyagiense* and *Sequoia gigantea*.

The height of the ray tissue in terms of the number of cells is shown in Table 10. The frequency polygon and the statistical constants are shown in Text Fig. 9.

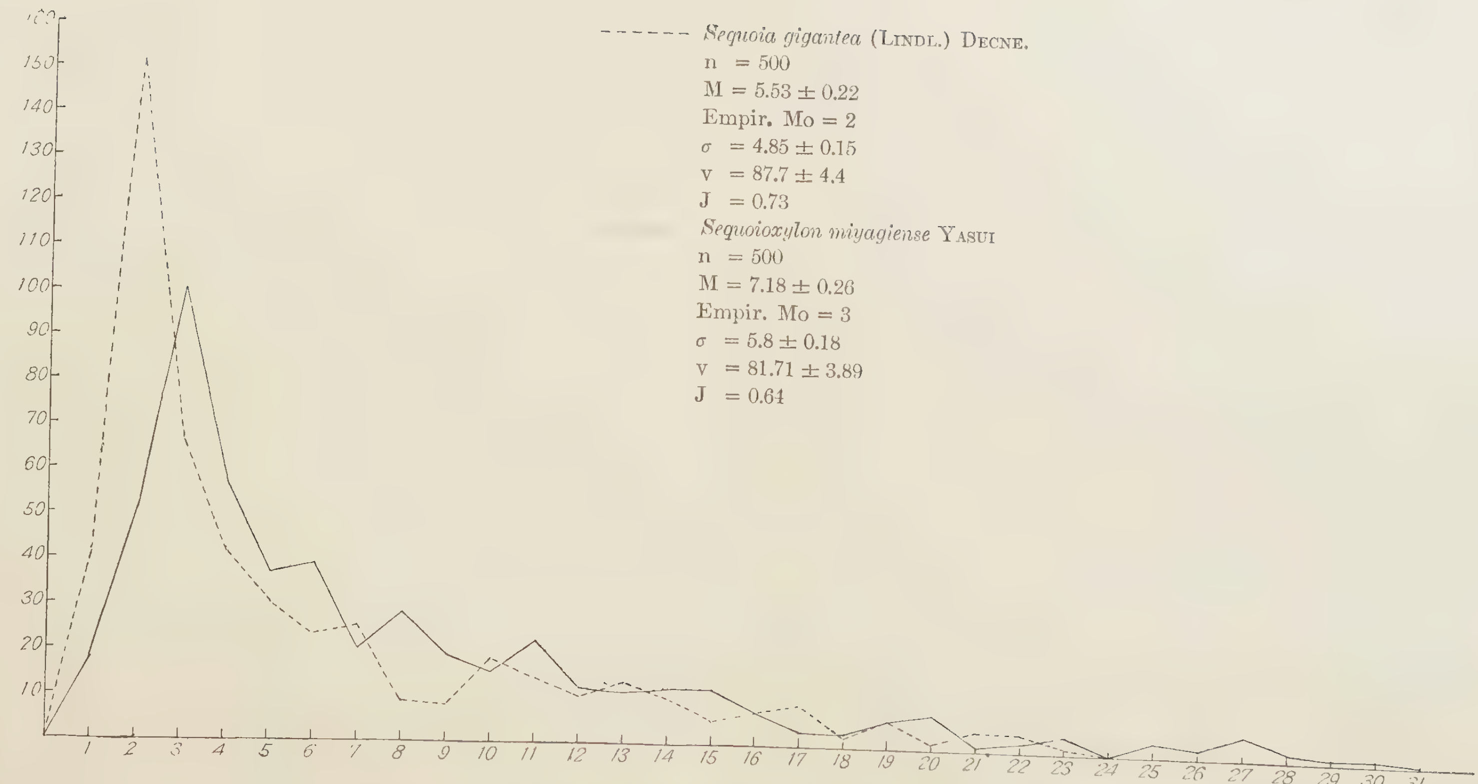
TABLE 10

Class value in terms of the number of cells of the height of ray tissues		1	2	3	4	5	6	7	8
Frequency	*Sequoioxylon miyagiense*	18	51	101	57	37	39	20	28
	Sequoia gigantea	41	153	68	42	30	23	25	9

Class value in terms of the number of cells of the height of ray tissues		9	10	11	12	13	14	15	16
Frequency	*Sequoioxylon miyagiense*	19	15	22	12	11	12	12	7
	Sequoia gigantea	8	18	14	10	13	10	5	7

Class value in terms of the number of cells of the height of ray tissues		17	18	19	20	21	22	23	24
Frequency	*Sequoioxylon miyagiense*	3	3	6	7	1	2	4	0
	Sequoia gigantea	9	2	6	1	4	4	1	0

Class value in terms of the number of cells of the height of ray tissues		25	26	27	28	29
Frequency	*Sequoioxylon miyagiense*	3	2	5	2	1
	Sequoia gigantea	0	0	0	0	0



Text Fig. 9. Frequency polygons of the height of ray tissues and their statistical constants in *Sequoioxylon miyagiense* and *Sequoia gigantea*.

The horizontal wall of the ray cell is thick and pitted; the terminal wall is thin, straight or somewhat curved; the pits on its lateral wall are small and bordered, 1 to 4 per tracheid. They mostly occur in one row, except in the marginal cells in which there are generally two rows of them. The orifice is oval, horizontal or somewhat oblique (Figs. 69 and 70).

In Fig. 72, (R) shows cross sections of resin canals. Resin canals are distributed in a tangential row and are lined with thin-walled secretory cells. Outside of the latter there are some septate tracheids, the transverse walls of which have bordered pits. As they are accompanied by septate tracheids and tangentially distributed, it is seen that the canals are traumatic, though the point of injury is not shown in the specimen.

Affinities. The structure of the wood mentioned above — the pitting of the ray cell, the distribution of the resin cell, the presence of 'bars of Sanio' and the traumatic resin canal — points to its affinity with the living *Sequoia sempervirens* and *Sequoioxylon hondoense*. But the pits in the radial wall of spring tracheids are quite peculiar to this wood and the other quantitative characters, namely the size of cells, the thickness of annual rings and the height of ray tissues, are also different from those of the wood of the two living species of *Sequoia* and of *Sequoioxylon hondoense*. These seem to justify a new name for this wood.

Diagnosis of *Sequoioxylon miyagiense* sp. nov.

Transverse section. Annual ring clearly defined; transition from spring to summer wood somewhat abrupt; summer wood very prominent and from three to fifteen tracheids in its thickness. The average ratio of the number of tracheids in spring and summer wood is 100 : 61.5. Spring tracheids very open. Resin cells prominent and scattered throughout the wood.

Radial section. Ray cell straight, somewhat resinous, equal to from two to four tracheids; horizontal wall thick and pitted; terminal wall thin, straight or somewhat curved, and not pitted; lateral wall with rather small bordered pits, one to four per cross area, mostly in one row except in the marginal cells in which there are generally two rows. Radial pits of tracheids round or oval in from one to three rows; when in more than one row the pits are arranged in parallel raws; 'bars of Sanio' prominent.

Tangential section. Ray tissue somewhat resinous, prominent and generally uniseriate, but rarely paired cells appear in uniseriate rays.

The statistical constants of the frequency polygon of the height of 500 ray cells are

$$\begin{aligned} M &= 16.47\mu \pm 0.12\mu \\ \sigma &= 2.6\mu \pm 0.08\mu \\ v &= 15.77 \pm 0.5 \\ \text{Emp. Mo} &= 16.25\mu \end{aligned}$$

The statistical constants of the frequency polygon of the height of 500 ray tissues in terms of the number of cells are

$$\begin{aligned} M &= 7.18 \pm 0.26 \\ \sigma &= 5.81 \pm 0.18 \\ v &= 81.01 \pm 3.89 \\ J &= +0.72 \\ \text{Emp. Mo} &= 3 \end{aligned}$$

Bordered pits on the tangential walls of the summer tracheids are small and in one or two rows.

This description is based upon a study of an old trunk of 100 or more years' growth.

Locality: Miyagi Prefecture. Tertiary.

f. **Coniferous wood from Manchuria**, Pl. XVII, Figs. 56–58.

Pl. XVII, Figs. 56–58 are microphotos of sections of pieces of Jurassic bituminous coal from South Manchuria. The color of a thin section of the coal is reddish brown, and the cell wall of the tissue in the coal do not show their characteristic physical properties between the crossed nicols.

Fig. 56 shows a somewhat oblique cross section of the wood. The annual ring is clear, and the tracheids in the spring and summer wood are open, and arranged in regular rows. No resin canal nor resin cell was observed in the tissue. The rays are obscure.

Fig. 57 shows a radial longitudinal section. The bordered pits on the radial wall of the tracheid are uniseriate in the summer wood, but those on the spring wood are not visible due to the bad preservation. The pits on the lateral wall of the ray cells are not clear, but seem to be of the Cupressoxylon type. No 'bars of Sanio' have been observed, but the distances between the bordered pits suggest that the pitting is not of the Araucarioxylon type.

Fig. 58 shows a tangential longitudinal section. Here the sections of bordered pits on the radial wall of the tracheids are shown very prominently, and the terminal pits also are shown. Ray tissue is not

well preserved, but still it is clear in the photograph that it is uniseriate and not high. Here also there is no sign of the presence of resin canals nor resin cells.

AFFINITIES. The structure of the wood shows some affinity to the Cupressoxylon type of wood generally, though the absence of resin canals and resin cells suggests other affinities, but the bad state of preservation makes it impossible to decide the point.

Locality: Sha-ho-tzu, Chang-tu Hsien, South Manchuria. Jurassic.

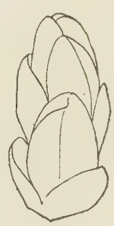
B. CONIFEROUS TWIGS

Text Fig. 10.

Two pieces of small twigs shown in Text Figs. 10 and 11 were found in lignite from the Séto seam, Aichi Prefecture, associated with *Pinites Fujiii*.

The twig shown in Text Fig. 10 is 2.5 mm. long and of a black color. The examination of the internal structure shows that the present specimen belongs to a conifer. The external appearance reminds us of branches of *Sequoia gigantea*, *Cryptomeria japonica*, a *Juniperus* and also *Cryptomeriopsis* among Japanese fossil conifers, so it may be referred to a plant belonging to one of these genera, especially because the wood types of these genera, Cupressoxylon and Sequoioxylon being found in the lignite from the same colliery. However, we may exclude *Sequoia gigantea* in considering the relationship of this plant, because of the absence of resin canals in wood of the first year's growth, which is characteristic to the latter plant. Unfortunately, the preservation of the internal structure is not good enough to make it possible to determine the closer affinities.

Text Fig. 11 is a tip of a small branch about 2 mm. long. It is black and flattened in one direction due to compression. From its external feature it may be referred to a tip of a branch of a juniper or some other conifers, but the internal structure could not be investigated.



Text Fig. 11.

C. A FOSSIL CONE

Pinites Fujiii sp. nov. Pl. XX, XXI, Figs. 80–94.

The specimen on which the present description is based is a detached cone. It was found in lignite from Séto in the Aichi coal-field,

Upper Tertiary. The specimen is somewhat obliquely compressed in the direction of the cone-axis, so that the length of the cone could not be measured, but the transverse diameter was about 45 mm., and judging from other circumstances the length was probably about the same.

Pl. XX, Fig. 80 shows the cone, seen from the base, Fig. 81 is the side view, and Fig. 82 shows it from the top. In general aspect the cone is unmistakably that of a *Pinus*. The seeds are not preserved, probably being shed ; but the remains of the tissue of the seed wing show that the cone was full grown.

The arrangement of the scales is shown in the Text Fig. 12 showing 8 plagiostachies of the cone scales. Every 22nd scale comes directly above the first; therefore the phyllotaxy of the cone is 8/21. Such a cone phyllotaxy is seen in several living species of *Pinus* belonging to *Diploxylon*, e.g. *Pinus Thunbergii*, *P. densiflora*, *P. luchuensis*, but the phyllotaxy is simpler in those belonging to *Haploxylon*, e. g. *Pinus strobus*, *P. pumila*, *P. parvflora*, *P. excelsa*, *P. koraiensis*, etc.

Text Fig. 12.

The axis. The preservation of the woody portion of the axis was not good, so that the secondary xylem of its wood did not come out perfectly in Pl. XX, Fig. 83, which is a microphoto of a part of the cross section of the axis. The central part is the pith whose diameter measures 8 mm. × 3 mm. This unequality in the diameter is simply the result of compression. The pith occupies a portion much larger than in the living hard pines, e. g. *Pinus Thunbergii* or *P. densiflora*, which have cones of about the same size as this fossil one. In these hard pines the pith measures generally 2–3 mm. in diameter. The pith consists entirely of parenchymatous cells as in those of the living pines above mentioned, and the cells are larger in the central part than in the periphery. The compression makes it difficult to determine the exact size of the cells in their normal state, but the smaller ones measure about 15

micra and the larger ones about 60 micra. There is no sign of the presence of resin canals in the pith.

Surrounding the pith there are a number of primary xylems, arranged in a ring, and separated by scale gaps. One of the latter is shown clearly in Pl. XX, Fig. 84, which is a microphoto of a part of a tangential longitudinal section of the axis through the primary xylem.

Pl. XX, Fig. 85 is a microphoto of a part of Fig. 83 highly magnified. The upper part of the figure shows the tissue of the pith, and the lower part the wood which is very much crushed and compressed, so that the details of the structure can not be seen clearly, but the middle part of the photograph shows several well preserved primary xylems. In the two living pines the protoxylem of the cone axis consists of very small tracheids whose diameters measure from 6 to 25 micra. The construction of the primary xylem of the axis of the fossil cone is similar to that in the living pines and the diameters of the tracheids also are alike, though they are compressed. Spiral tracheids were observed in the protoxylem in which they were clearly shown; the tracheids of the secondary xylem have bordered pits, but their preservation is not satisfactory.

Ray tissue in the wood is uniseriate. Unfortunately, the height of the ray tissue could not be determined due to the bad state of preservation of the tissue.

In the early developed secondary xylem several large resin canals (c) are discernible as may be seen in Figs. 85 and 87. In the latter, a part of the primary xylem more highly magnified, is shown.

Pl. XX, Fig. 86 is a microphoto of a part of the axis of a cone of a living pine. In the upper part of the figure the pith, and in the lower part the primary xylem and the early developed secondary xylem may be seen. In the latter we have almost the same structure as that of the fossil cone; (c) is one of the resin canals.

The development of the phloem in the axis of the fossil cone is not good, and the cortex and epidermis of the axis are not well preserved.

The cone scale. The larger scales measure 12–13 mm. across the broadest edges and 3–4 mm. in the thickest part. They are generally wedge-shaped with the point drawn out into a hook. The latter is elongated and deflected in the scales of the middle part of the cone, while in those at the base of the cone the hooks point directly downward. No bract-scale was observed.

Pl. XXI Fig. 88 shows a half of a cross section of a scale of the present fossil cone. In the middle of the scale are distributed the vascular bundles, the number of the latter being 11 in the basal part of the apophysis where the scale is broadest. The connection between these bundles and those of the axis could not be made out.

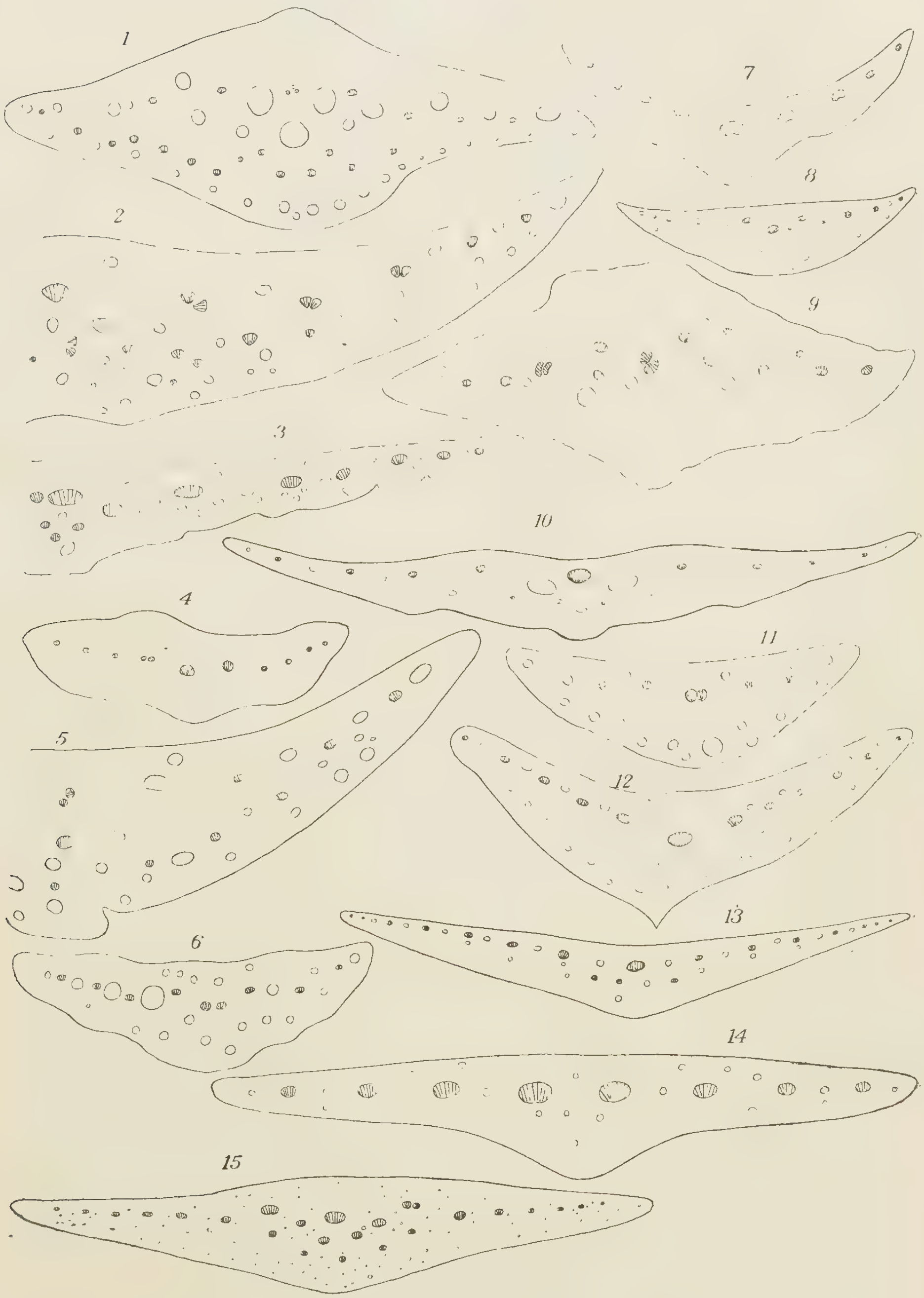
Pl. XXI, Fig. 89 is a microphoto of a part of a cross section of a scale, the upper end of the figure showing its upper surface and the lower end the lower surface. The epidermis of the scale is not well preserved, but consists of small thick walled flat cells measuring about 25×8 micra. No stomata were seen in the epidermis. The hypodermis consists of a few layers of large sclerotic cells. The size of these cells differ in different parts of the scale, but they are generally larger on the upper side of the scale than on the lower side, and more numerous on the lower side of the scale than on the upper side.

In the lower hypodermal tissue several resin canals were observed. They are small and rather few in number. Pl. XXI, Fig. 91 shows a cross section of the resin canal. Its secretory cells have thin cell walls, though they do not come out clearly in the photograph due to the bad preservation.

The tissue between the upper and lower hypodermal layers consists mostly of parenchymatous cells. They are very much compressed except some stone cells which are scattered among the latter.

Pl. XXI, Fig. 89 is a microphoto of a part of the upper side of the scale including one of the vascular bundles, highly magnified. It shows the protoxylem situated on the upper side whence the metaxylem and secondary xylem continue toward the upper surface of the scale. In the Fig. 92 (c) is the resin canal which shows plainly in the tissue of the early developed secondary xylem. The resin canal is shown more clearly in Fig. 90 (c), which is a microphoto of a longitudinal section of the same scale.

Text Fig. 13. Cross sections of the cone scales of 15 species of *Pinus*. Blank spots represent resin canals; shaded ones, vascular bundles. 1, *Pinus cembra*, L. var. *manchurica*, MAST., × 5; 2, *P. parviflora* S. ET Z., right half of a scale, × 5; 3, *P. excelsa* WALL., × 5; 4, *P. longifolia*, SHAW, ×2.5; 5, *P. koraiensis*, S. ET Z., right half of a scale, × 5; 6, *P. densiflora* var. *umbraculifera*, MAYR, × 5; 7, *P. Banksiana*, LAM., × 5; 8, *P. silvestris*, L., × 5; 9, *P. pumila*, RGL., × 5; 10, *P. strobus*, L., × 5; 11, *P. densiflora*, S. ET Z., × 5; 12, *P. montana*, Mill., × 5; 13, *P. monticola*, SCHRÖTER, × 5; 14, *P. pinaster*, SOLAND., × 5; 15, *P. Sabiniana*, DOUGLAS, × 2.5.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The protoxylem consists of several spiral tracheids, and the metaxylem and secondary xylem of small slender tracheids. The pits on the latter could not be determined, due to bad state of preservation.

Pl. XXI, Fig. 94 is a microphoto of a part of a cross section of a cone scale of a living pine, *Pinus Thunbergii*. When this scale is compared with that of the fossil cone: 1, the fossil scale is thicker than that of the living species; 2, the epidermal cells are larger in the living form; 3, the hypodermal tissue of the living species is very much thinner than that of the fossil; 4, the number of the vascular bundles is larger and their development is better in the fossil than in the living species; 5, the development of the resin canals is better in the living pine, in which they are distributed on both sides of the scale, while in the fossil cone they occur only on one side.

Seeds were not observed, but the scars left on the scales show that they were small, and a remaining fragment of a seed wing shows that the wing was well developed, and not small.

Affinities. The external characters and anatomy of the fossil cone testify that it belongs to the genus *Pinus*.

Pilger (1926) divided *Pinus* into two subgenera *Haplo-* and *Diploxylon*. Those pines which belong to *Haploxylon* have cones, with the umbo situated at the end of the scale, except those in section III, which have mostly big seeds; therefore judging from external characters the fossil cone seems to be remote from those pines belonging to *Haploxylon*.

The writer has examined the internal structure of the cone scales of the *Haploxylon* in *Pinus pumila*, *P. koraiensis*, *P. cembra*, *P. excelsa*, *P. parviflora*, and *P. strobus*.

As is shown in Text Fig. 13, in these species the vascular bundles in the scale (in the broadest part of the scale) are scattered throughout the scale, but not in a single series. The bundles are rather small but numerous, the resin canals well developed and distributed throughout the scale. Thus the internal structure of the *Haploxylon* cone-scales is not similar to that of the fossil ones.

The second subgenus *Diploxylon* contains 8 sections, but the diagnostic characters enumerated by Pilger are not applicable to the present cone, therefore the anatomical structure of the cone scale alone must be relied upon for the determination of the affinity.

The *Diploxylon* species of which the writer studied the internal structure of the scale were the following ten species: *Pinus longifolia*,

P. densiflora, *P. sylvestris*, *P. Thunbergii*, *P. luchuensis*, *P. montana*, *P. pinaster*, *P. Banksiana*, *P. monticola*, and *P. Sabiniana*.

The scales of the first five species have rather small vascular bundles distributed in a somewhat irregular row, and the numerous resin canals distributed throughout the scale; in *P. monticola* and *P. Sabiniana*, especially in the latter, the vascular bundles are numerous and the distribution is somewhat complicated, the resin canals being small and quite numerous, as is shown in Text Fig. 13; and in *P. Banksiana*, *P. montana*, and *P. pinaster*, vascular bundles are arranged in one row with regular intervals, resin canals being smaller in number and distributed throughout the scale.

On comparing these scale structure, together with other details, with that of the fossil cone, we come to the conclusion that the cone of *P. pinaster* comes very close to the fossil cone, though the external characters are different.

We have no living pine in Japan with which this fossil may be identified, and so far as the writer is aware probably no such fossil cone was ever before discovered.

Accordingly the writer has decided to name the present cone *Pinites Fujiii* in honour of Prof. KENJIRO FUJII, who gave the writer this fossil cone for study.

It is rather curious that the writer did not meet with any piece of wood of the Pityoxylon type in the coal which she examined, notwithstanding the fact that there are some reports on the Pityoxylon type of wood from Hokkaidō (REISS 1907) and some *Pinus* species from the northern part of the Mainland of Japan (YOSHIWARA, 1898, 1900), and even in the Japanese Cretaceous there were described some fossil remains of leaves of pines (STOPES and FUJII, 1910; STOPES and KERSHAW, 1910; FUJII, 1910).

Diagnosis of *Pinites Fujiii* sp. nov.

The cone is about 45 mm. in diameter, of about the same length, and of somewhat conical shape. It has a short slender stalk. The phyllotaxy of the scales is 8/21. The end of the scale is generally wedge-shaped with the point drawn out into a hook. In the middle part of the cone the hook is elongated and deflected, while at the base it points downward.

The pith is large, but neither resin canals nor large stone cells are developed in it. The distribution of the vascular bundles in the axis of the cone is very much like that of the living pine, *P. pinaster*.

The number of the vascular bundles in the broadest part of the scale is about 11 in a large scale. The structure of each vascular bundle

is very much like that of *Pinus pinaster*. They are rather large and arranged in one line in the central part of the scale. The hypodermal cells are well developed, especially on the lower side of the scale; the cells are larger on the upper side. Several stone cells are scattered in the parenchymatous tissue which forms the internal part of the scale and in which the vascular bundles are distributed. Resin canals in the scale are rather small and are distributed mostly on the lower side of the scale.

Seeds small; seed-wing well developed.

Locality: Séto in Aichi Prefecture, Central Japan. Upper Tertiary.

D. Angiospermous wood

Angiospermous wood in the coal from our coal-fields is generally in a bad state of preservation, and in a majority of cases is of a fragmental nature, so that its taxonomic determination is in many cases impossible. The two specimens now to be described are rather exceptional. One is from Futto in Aichi Prefecture, and the other from Nagano, neither is from the main coal-field.

a. **Angiospermous wood. No. 1.** (Pl. XIX, Figs. 74–77).

Fig. 74 shows a cross section of the wood. The parallel black stripes show the diffused rays, and the tissue between them is that of the secondary xylem. The group of large cells scattered here and there are the parenchymatous tissue in which vessels are situated, aud the other part consists of fibrous cells or wood fibers.

Fig. 75 shows a radial section of the wood, but on account of the bad preservation of the cells there is nothing particular to be seen except the fungal hyphae penetrating the tissue.

Fig. 76 is a tangential section of the same wood, in which we can see some traces of the diffused rays and the fungal hyphae grown throughout the tissue.

Such poor preservation as is described here does not admit of any taxonomic identification of the specimen, but still the presence of the diffused rays and the nature of the wood tissue clearly show the angiospermic character of the wood.

Locality: Nagano Prefecture. Tertiary.

b. **Angiospermous wood. No. 2.** (Pl. XIX. Figs. 78–79).

This wood specimen from the Aichi coal-field measured nearly five cm. in diameter, but on account of the bad preservation the cross section

of the wood hardly shows the structure of the wood. Pl. XIX, Figs. 78 and 79 which are microphotos of tangential sections of the same piece of wood show, however, some characteristic features of the tissue. The middle part of Fig. 78 shows a broad well developed compound ray tissue, and the large blank portion on both sides of the ray tissue shows the cavities of large vessels. On both sides of them tissues composed of wood fibers are seen. Such fibers are shown very clearly in the right of Fig. 79. Among these wood fibers there are many uniseriate ray tissues and wood parenchyma, though they are not sharply defined.

In woody vascular plants such large compound ray tissue has a somewhat limited distribution, namely they are found only in *Ephedraceae* in the higher gymnosperms, *Casuarinaceae* and *Fagaceae* in the lower angiosperms. The wood, now under consideration, does not show special characters of the wood of *Casuarinaceae*, and *Ephedraceae* has not such a large stem ; consequently, the fossil wood must belong to the wood of a *Fagaceae*.

In general features the wood much resembles a piece of 'sakurazumi' (a kind of charcoal made from wood of a *Quercus* species, which is in common use in Japan), though the fossil was much more friable than the charcoal.

Provisional name: *Dryoxylon chitaense* sp. nov.

Locality: Futto, Aichi Prefecture, Central Japan. Upper Tertiary.

E. Moss

Polytrichites gen. nov. **aichiense** nom. nov. (*Bryotrichum aichiense* Yasui) (Pl. XXII, Figs. 95–103).

As far as the writer is aware, with the exception of the writer's previous report on this moss, the descriptions of fossil mosses hitherto given have been based on their external feature in impressions. External features are, however, sometimes misleading, especially in a lower plant with simple structure. As is now generally held, the internal structure is more reliable in this respect. Consequently it seems not to be superfluous to describe the internal structure of a specimen of a fossil moss, although the nature of the present material is far from being satisfactory for the purpose.

Several specimens, on which the present investigation is based, were found in lignite from the Aichi coal-field, and identified as the stems of gametophytes of a certain moss. A microphoto of a cross section of one of the specimens is shown in Fig. 95 (M). It is in a compressed state and measures about 1 mm × 0.1 mm. The cells in the outer-

most layer or the epidermis, are small, being ca. 5 to 9 micra in tangential diameter. They are flattened by compression, so that their cavities are badly represented. The cell of the epidermis is dark brown under the microscope. Neither stomata nor trichome are observed on the epidermis.

In a cross section of the specimen, there are two or three layers of small thick-walled subepidermal cells of from 5 to 15 micra in diameter. They are followed by one or two layers of large thick-walled cells, 30 micra or more in diameter; the length of these cells in longitudinal section measures 70 to 120 micra. The wall of the latter is very thick measuring 5 to 12 micra. The cell wall of all these thick-walled cortical layers is light yellow under the microscope.

The central part of the cross section of the stem, as is shown in Fig. 96 (a), is occupied by a tissue composed of hexagonal cells about 8 micra in diameter. Fig. 98 is a microphoto of a cross section of another specimen which has been determined to be of the same species. In this, the central part of the section is shown in a better condition, though the preservation of the outer part is not perfect. Between this central tissue and the thick-walled tissue above described, there is a tissue of thin walled cells which is badly compressed, so that the details of its structure are hardly recognizable except in some limited parts. Also, about midway in the photograph and lying crosswise is a distinct tissue layer one or two cells thick, (Fig. 96, b). In contrast to the badly preserved thin-walled tissue, this tissue layer is well preserved, and the cell wall in this tissue is yellowish brown under the microscope. This is evidently the endodermis which divides the main mass of the tissue of the specimen into two parts, the outer cortical tissue and the inner central cylinder. We see in the photographs that the outer part of the central cylinder is also badly preserved.

Now we can locate in the specimen, the epidermis, cortex, endodermis, and central cylinder, of which the cortex is differentiated into the outer thick-walled tissue and the inner thin-walled parenchymatous tissue, while the central cylinder consists of the central xylem and the outer badly preserved phloem.

In Pl. XXII, Fig. 102, a special tissue (l) is shown, which is rather well preserved, and consists of a number of cells. There is no connection between this tissue and that of the central xylem, though it probably lies within the endodermis. This tissue is evidently that of a leaf trace.

Pl. XXII, Fig. 100 is a microphoto of a cross section of another part of the same stem from which the photograph in Fig. 98 was taken.

Here we see a part of the leaf base (s) attached to the stem, and one cell thick in this part. Besides, there are two of detached leaves shown in Figs. 97 and 101 and a leaf attached to a stem, observed in the same matrix. One of the former has the same structure as the latter. The stem of the latter resembles the stem described above but is simpler, so that the writer hesitates to bring them under one species. Consequently, whether these two kinds of leaves belong to the present plant or not, is for the present left undecided.

There is no plant organ known, whose structure is such as above described, other than the aerial stem of a gametophyte of a certain group of mosses. For comparison a microphoto of a cross section of a stem of the gametophyte of a moss of common occurence, *Polytrichum commune*, L. is given (Pl. XXII, Fig. 99). The outermost layer is the epidermis, which is dark brown under the microscope. The tissue, inside the epidermis, consists of cells like that of the fossil. This thick-walled tissue is followed by the inner cortical tissue, which consists of thin-walled parenchymatous cells. The central cylinder is bounded externally by an endodermis just as in the stem of the present specimen. A comparison of Fig. 99 with Figs. 95, 96, 100, and 102 will demonstrate the identity of the structure of the central cylinder, leaf traces (l), and the leaf base (s), in the present fossil specimen and those in *Polytrichum commune*, L.

In *Polytrichum* of the present day the cell wall of the thick outer cortex as well as of the xylem is somewhat lignified, and has the property of double refraction like the wall of the parenchymatous cell of higher plants. It is noteworthy that this optical property is perfectly retained in the fossil specimen and exactly in the same manner as in the cell wall of the living *Polytrichum*. Pl. XXII, Fig. 103 is a microphoto of the same specimen from which Fig. 96 was taken; the former was taken with crossed nicols, and shows the phenomenon of double refraction clearly. The interference color of the wall of a cross section of the thick-walled cells between the crossed nicols with the insertion of the gypsum plate (red I) in the usual way, is yellow in the first and third quadrants (the subtraction-color) and in the second and fourth quadrants blue (the addition-color).

This coincidence in their anatomical structure and the optical behavior of the tissue, together with the diminutive diameter of the specimen in question leads us to the conclusion that the fossil specimen is an aerial stem of a gametophyte of a moss with a closer affinity to *Polytrichum*.

The writer previously named this plant *Bryotrichum aichiense*, on account of the absence of leaf traces in the section, and also of the smooth surface of the specimen; but later investigations have shown that the stem had leaf traces and attached leaf bases as well, so that the writer now proposes the new name, *Polytrichites aichiense.*

Diagnosis of *Polytrichites* gen. nov. *aichiense* nom. nov.

The diameter of the cross section of the stem is about 0.7 mm. The differentiation of the tissue of the stem is advanced, epidermis and cortex being clearly distinguishable, with the central cylinder very prominent; also leaf traces occur. The tangential diameter of the epidermal cell is 5 to 9 micra, and the radial diameter is still smaller. Under the epidermis, there are two or three layers of small thick-walled subepidermal cells, whose diameters measure 5 to 15 micra. They are followed by one or two layers of large thick-walled cells 30 micra or more in diameter, the length of these cells in longitudinal section measuring 70 to 120 micra. The walls of the innermost thick-walled cells measure 5 to 12 micra in diameter. The central cylinder consists of central xylem with hexagonal cells about 8 micra in diameter, and phloem, which in this specimen is badly preserved. Surrounding the central cylinder the endodermis is well developed. Between the endodermis and the thick-walled cortical layers there is the inner cortex consisting of thin walled parenchymatous cells. The property of double refraction of the cell wall is promiment in these thick-walled cells as well as xylem cells.

Leaf traces are preserved in some parts, but cannot always be detected.

Locality: In lignite from the Aichi coal-field, Central Japan. Upper Tertiary.

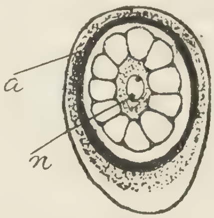
F. Fungi

a. Pl. XXIV, Fig. 117 (a) shows a microphoto of a part of a section of a fungal mass in a piece of coal from the Ju-has-shaku seam in the Takashima colliery. The whole mass measured about 2 mm. long, 1.5 mm. wide, and about 0.3 mm. thick. The matrix-like part of the mass consisted of a transparent homogeneous material, which was whitish yellow to bright yellow under the microscope. In the matrix the body of fungus was embedded. The branched septate hyphae were brown under the microscope and the cells measured 2–3μ wide and 3–8μ or more long.

The conidia, as are shown in Pl. XXIV, Fig. 117, (b), generally consisted of one row of from three to seven cells, but were sometimes branched. The cells were generally spherical, but sometimes cylindrical, and measured about 8μ in diameter, and the color was brown under the microscope.

There were observed many isolated spores together with the conidia at one side of the matrix, as are shown in Pl. XXIV, Fig. 117, (c). Pl. XXIV, Fig. 117, (d) shows a microphoto of one of such spores with a higher magnification. It had thick cell-wall and in the center of the cell a small body, presumably a nucleus, was observed in the cytoplasm-like remains. Surrounding the latter there were recognized a number of bright colorless areas, possibly vacuoles, closely arranged in a ring.

In one case there was observed that such a spore presented an appearance that it was formed in a conidial cell of the fungus, with some cytoplasm- like remains left between the wall of the spore and that of the conidiospore as are shown in Text Fig. 14.



Text Fig. 14. Spore of a fungus. The outermost wall is the wall of conidiospore; a, seemingly the cell wall of the spore formed within the latter n, nucleus? × 1500.

Whether the transparent homogeneous yellow matrix belongs to the very fungus or not, is not ascertained yet, and the affinity of the fungus is difficult to be determined.

b. In Pl. XXIII, Fig. 111, (s) represents a section of fructification of a fungus. The body is generally spherical, but sometimes ellipsoidal or of irregular shape. It consists of small cells which are brown. The size is sometimes as large as 0.3 mm. in diameter, but generally it is about 0.1 mm., and occasionally it is very small, consisting of only a few cells. The diameter of the cell is about 15 micra. The fructification appears generally in association with some brown colored hyphae, as shown in Fig. 114, though the actual connection between them is very rarely observed. JEFFREY and CRYSLER described a fungus in the tissue of some angiospermous wood from Brandon, Canada, and named it *Sclerotites brandonianus.* The specimen now in question closely resembles it, though here the average size of the fungal body is somewhat larger.

Provisional name : *Sclerotites nipponianus.*

c. Pl. XIX, Fig. 75 is a microphoto of a fossil angiospermous wood in which remains of a fungus are shown. The hyphae are developed in the tissue of the wood. The fungus grew longitudinally in the tracheal cell cavities and transversely through the pits of the cells of the host. It is pale brown and the diameter of cross sections of hyphae measures 1.5 to 5 micra. It is septate and branched several times, the length of the cell being about 15 to 23 micra. The transversely developed hyphae are swollen up in the cavities of the cells. Conidia are developed on the tip of the branch of the hyphae.

The conidium consists of 5 to 11 cells arranged as is shown in Fig. 77. The cells of the conidium are 15 to 27 micra long and 8 to 12 micra in width. The color of the conidium is deeper than that of the hyphae.

In 1894, Felix described the fossil fungi, *Haplographites cateniger* and *H. xylophagus*, in which the conidia were in chain and consisted of 6 cells in the largest conidium. They somewhat resemble the present specimen, though in the latter the conidia are larger and the cells are rather cylindrical and not oval or cask-shaped.

Locality: From a lignite seam, Asahiyama, Nagano Prefecture. This specimen was found, associated with some remains of Cupressoxylon-type wood and fossil walnuts.

d. Pl. XXIII, Fig. 112 shows another specimen of fungus. In appearance it is very much like specimen (b), but it occurs always in parenchymatous cells, most of which belonged to some higher plants; sometimes it filled up the cell cavity.

Pl. XXIII Fig. 115 represents a fungus in the bark of living *Cunninghamia*. The hyphae spread through the parenchymatous cells and forms conidia-like bodies in the cells. A comparison suggests the close affinity between these two fungi. It is not impossible that their host plants, too, are allied to each other.

G. Algae and Diatoms

a. Pl. XXIII, Fig. 108 is a microphoto of a 'parallel section' of lignite from Takahari, Aichi Prefecture. This figure shows a unicellular organism which measures about 25 micra in length, its breadth being about 2/3 of its length. In the center of the cell, there is shown a knot. From each side of the knot a stripe runs toward the end of the longitudinal axis of the cell. These two lines run in opposiste directions and both ends of the body itself are also inflected oppositely from each other.

This structure of the cell closely resembles that of certain diatoms, e.g. *Pleurosigma angulata*, the knot at the center being the central nodule, and the stripes the raphe or binding canals.

One more specimen shown in Pl. XXIII, Figs. 109 and 111 (d), which may be referred to a diatom, was found.

Text Fig. 15. A piece of filament of an alga in lignite from Takahari. ca. × 700.

b. Text Fig. 15 shows a piece of an alga which was found in a section cut at right angles to the bedding plane of lignite from Takahari, Aichi Prefecture. A number of similar specimens were observed. The body is filamentous, consisting of one row of cells which measure about 4 micra in breath and 14 micra or more in length. The cell, shown in the upper part of the figure seems to have some traces of sculpture on the cell wall; at the upper end of the lower cell in the figure there is a collar-shaped portion. The wall of the lower cell, having no sculpture, is thin, smooth, and colorless. Inside the cell, there are some remains of cell contents, which are light brown.

This specimen may be referred to *Oedogonium*, one of the most distinctive genera of the Chlorophyceae. The filaments of *Oedogonium* show intercalary growth, and causes the formation of the collar-shaped cap on the wall at an end of the cell. The lower cell of the present fossil filament probably corresponds to the newly arisen cell.

H. Spores and pollen grains

Since Jeffrey established the fact that *Pila bibractensis* Bertrand et Renault is the spore of a pteridophyte and does not consist of algal remains as it was maintained by some authors, the attention of investigators in coal has been much drawn to the spores in coal, and several kinds of spores have been recognized.

In bituminous coal and lignite in Japan, also several kinds of spores and pollen grains have been found in the course of this investigation. They are in our case not very important components of coal on account of extremely small quantities in which they occur, but they may be very important for the determination of the coal-forming flora and also for the question of the origin of coal, as was shown by Jeffrey.

The spores and pollen grains in coal and lignite are compressed in the direction perpendicular to the bedding plane, so that in the section

at right-angles to the bedding plane they are flattened and do not show their structure well enough to determine their morphological nature, but in the section cut parallel to this plane they are shown more clearly.

The pollen grains and spores met with in Japanese coal and lignite during this investigation are as follows:

a. Pollen grains

1. Pl. XXIII, Fig. 104 is a microphoto of a tetrad-type pollen grain, in which the tetrads derived from one microspore mother-cell do not separate from one another as they do usually. The diameter is about 25 micra. The thin section of the cell wall of the grain is yellow under the microscope, and the property of double refraction of the wall is retained in some grains in lignite from the Aichi coal-field.

In some grains, the pores which are found in the middle part of the contact line of the cell wall between every two grains on the surface of the compound grain, are seen clearly. The cell cavities are empty, and the two lamellae of the cell wall, exine and intine, are not distinguishable.

The pollen grains of similar kind were observed in lignite from other seams in the same coal-field, in lignite from Sendai, and also in coal from Nagakura. They measured 25–44 micra in diameter.

Among the living plants such characteristic pollen grains are found in some families in Ericales and in some species in Cyperaceae.

Pollen grains in five families in Ericales were examined by the writer, with the results given in the following table:

Plant name	Family	Tetrad-form	Diameter in micra
Clethra barvinervis, S. et Z.	Clethrac.	−	
Shortia uniflora, Maxim.	Diapensiac.	−	
Sh. soldanelloides, Mak. var. *genuina*, Mak. f. *typica*, Mak.	"	−	
Sh. soldanelloides, Mak. *genuina*, Mak. f. *alpina*, Mak.	"	−	
Diapensia lapponica, L.	"	−	
Monotropa uniflora, L.	Pirolac.	+	28
Pirola elliptica, Nutt. var. *minor*, Maxim.	"	+	32
P. Faurieana, Andr.	"	+	32
P. rotundifolia, L. var. *genuina*, Herd.	"	+	32
P. nephrophylla, Andr.	"	+	32
P. renifolia, Maxim.	"	+	32

Plant name	Family	Tetrad-form	Diameter in micra
P. incarnata, FISCH.	Pirolac.	+	24
P. secunda, L. var. *vulgaris*, Herd.	,,	−	16
P. uniflora, L.	,,	+	28
Phyllodoce Pallasiana, DON	Ericac.	+	30
Tsusiophyllum Tanakae, MAXIM.	,,	+	30
Tripetaleia paniculata, S. ET Z.	,,	+	38
Arctous alpina, NIEDZ.	,,	+	38
Menziesia multiflora, MAXIM.	,,	+	32–38
Vaccinium Vitis-idaea, L.	,,	+	32–40
Leucothoe Grayana, MAXIM.	,,	+	30
Gaultheria pyroloides, HOOK. ET THOMS.	,,	+	25
Cassiope lycopodioides, DON	,,	+	20–28
Loiseleuria procumbens, DESV.	,,	+	38
Andromeda polifolia, L.	,,	+	40
Menziesia pentandra, MAXIM.	,,	+	30
Enkianthus campanulatus, NICHOLS.	,,	+ and −	30
Rhododendron sinense, SWEET	,,	+	48

The determination of the plants, that produced such tetrad pollen grains in lignite and bituminous coal in Japan is difficult, but their wide distribution and very frequent occurrence in coal suggest some dense growth of the plants in question, and the suggestion that most of them belonged to the Ericaceae, seems plausible.

2. Pl. XXIII, Fig. 105 is a microphoto of a section, cut parallel to the bedding plane, of a piece of lignite from the Kōzōji seam in the Aichi coal-field. (P) in this figure is a pollen grain. It is ellipsoidal in shape, and about 20 micra long and 16 micra broad; it also shows the longitudinal ridge on it. Pollen grains of the same structure were found in specimens not only of lignite from other seams of the same coal-field and from Sendai, but also of coal from Nagakura, as is shown in Fig. 106. Their structure is too simple and not sufficiently characterized, however, to admit of any determination of plants to which they belonged.

3. Text Fig. 16 shows an ellipsoidal pollen grain which was found in lignite from the Aichi coal-field. The major diameter measured about 30 micra, and the body consisted of one large and two small cells, the latter having a nucleus-like body each, but in the former no such structure was seen.

Only one pollen grain of this kind has been met with, so that this may be a rarer form preserved in Japanese lignite, notwithstanding the fact that the wood of conifers, whose pollen grains resemble the present form, are the dominating material in our coal, not only in lignite but also in bituminous coal from almost all parts of Japan.

Text Fig. 16. A pollen grain in lignite from Aichi coal-field. ×750.

4. Text Fig. 17 shows another example of a pollen grain isolated from lignite from the Aichi coal-field. The diameter measures about 20 micra, but in the pentagonal upper surface the diameter is smaller than in the basal surface and the height is about 1/3 of the diameter. There are five depressions on the lateral surface as shown in the figure.

Text Fig. 17. A pollen grain in lignite from Aichi coal-field. ×1400.

Pollen grains like this is found in some *Alnus* species among living plants, e. g. *Alnus sibirica*, var. *tinctoria*, Koidz., though in the latter some pollen grains show the pentagonal surface on two sides, while others are squarish.

Such fossil pollen grains appear more frequently than the coniferous pollen grains, but in a rather small number of cases, as compared with those of tetrad type.

b. Spores

1. Pl. XXIII, Fig. 107 is a microphoto of a section, cut parallel to the bedding plane, of a lignite from the Takahari seam in the Aichi coal-field. In this a median section of a spore is shown. The spore is almost spherical, but somewhat flattened. The shorter diameter is about 25 micra. The inner part of exine is very prominent, but the outermost part of it is not so distinct, and looks porous. On the top of the figure there is a slit which forms a part of the tri-radiate ridge, the dehiscence line on the surface of the exine. This tri-radiate ridge on the spore is a character of the spore of ferns or allied plants. In this spore there are some contents filling the cavity, so that the latter is not empty as it might be expected.

2. Pl. XXIII, Fig. 110 is a microphoto of a section, cut parallel to the bedding plane, of a coal from Nagakura. In this, two spores, (P_1) and (P_2), are shown clearly. They are tetrahedral and have some sculpture on the surface. One of them, (P_2), shows the tri-radiate dehiscence slit, which is somewhat open. These spores are smaller than

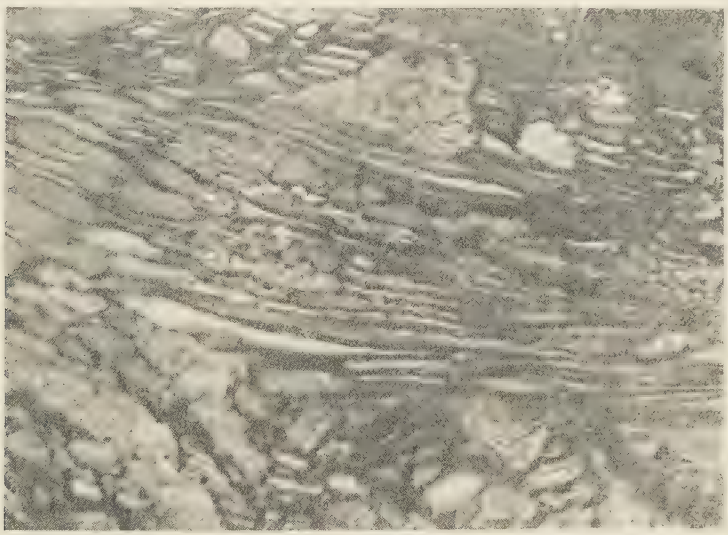
the one mentioned above, and belong to a different kind of plant, though the corresponding species of plants can not be determined.

Such tetrahedral spores have been found in several cases in lignite and bituminous coal from several localities in Japan.

VI. The vegetable elements in different coal seams in Japan

A. Coal from the Ibaraki and Iwaki collieries

The coal from the Ibaraki and Iwaki collieries as far as I have examined it, shows similar structures in their vegetable components, therefore they are here described together.



Text Fig. 18. Coniferous wood in coal from the Nagakura colliery. ×500.

Text Fig. 18 shows a photograph of a section of a coniferous wood from the Nagakura colliery. Here we see clearly the cross and tangential sections of tracheidal tissue, and in the latter the tangential section of the bordered pits on the lateral wall of tracheids are also clearly seen.

Pl. XI, Fig. 20 is a microphoto of a section, cut perpendicularly to the bedding plane, of the coal from the Nagakura colliery, the specimen having been obtained at a point about 15 cm. below the upper surface of the seam. The wood is very much compressed, so that the details of the structure in the tissue are not clearly shown, but it furnishes characteristics sufficient for the microscopic identification of

the tissue. The wavy black lines represent the ray tissue which is resinous, and the remaining parts consist of tracheidal tissue. Consequently this specimen is to be recognized as a piece of a coniferous wood.

In the upper part of Pl. XII, Fig. 24, we see a cross section of wood, and in the lower part of the same figure, there are two stripes of tissue which show the characteristics of cork tissue (c 1, c 2). This figure is a microphoto of a section of a piece of coal, which was obtained from the middle part of the same seam.

Pl. XI, Fig. 18 shows a microphoto of another part of the section represented in Pl. XII, Fig. 24. Here we have a section of wood in which the cells composing the tissue are clearly discernible.

Pl. XII, Fig. 23 is a microphoto of another 'perpendicular section' of a piece of coal which was obtained from the same seam as that from which the photograph in Fig. 18 was taken. Several white stripes of tissue are shown, which were identified as the epidermis of leaves, of which a description has already been given. From the figure we can see that this part of the coal is composed of piles of leaves, probably angiospermous, and that the cuticle and the cutinized walls only were well preserved due to the strongly resistant nature of the tissue. The other parts of the tissue is represented as black and almost amorphous masses between the white stripes.

Pl. XXIV, Fig. 116 is a microphoto of a section of the same piece as that in Pl. XII, Fig. 24; but this is a section cut parallel to the bedding plane, while that of Fig. 24 was cut perpendicularly to the latter. The large black spot in the central part is a sclerotium and the small roundish black spots are fungal spores. The former measures about 125μ in diamter and consists of several cells, but the latter consists of single cells. The small black bars are fragments of fungal hyphae. They are all reddish brown in color.

Pl. XXIII, Fig. 106 is a part of Fig. 116, more highly magnified. The white spot (p) in the central part of the figure is a pollen grain which is smooth and ellipsoidal, and measures about $50\ \mu$ in length. This is an example of the larger ellipsoidal pollen grain. The smaller sized grains are sometimes only $25\ \mu$ long. Each grain has a fold but their simple structure, as was mentioned above, makes it difficult to determine the plants which produced them.

Pl. IX, Fig. 3 is a microphoto of a 'parallel section' of a piece of coal from the Ibaraki colliery, the piece having been taken from the middle part of the working seam. The explanation of the figure has already

been given; it shows remains of a tissue of an angiospermous leaf. Another specimen of a leaf with the same structure as the latter was found from the upper part of the same seam.

Pl. XII, Fig. 29 is a microphoto of a section of a piece of coal from the same seam as that of Fig. 3, but from a different part, which was located about 15 cm. above the bottom of the seam. In this the darker-colored portion at the middle of the figure shows a cross section of a twig. The wood occupies the central wide portion of the twig. The outer darker-colored zone is the bark, the main part of which consists of cork tissue. The outermost part of the twig is lighter in color again; this part represents the older part of the cork tissue. Fig. 30 shows the cork tissue of the same specimen highly magnified, and details of the tissue is clearly shown.

A more detailed account on this cork tissue was already given in Cap. III, B, c.

Pl. XI, Fig. 19 represents another part of the same section, and shows a coniferous wood in which the resin cells and some tracheidal cell remains are still prominent, but most of the tracheids are in a condition which makes it difficult to recognize them.

From the above mentioned examples, we see that the coal from the Ibaraki and Iwaki colliery, so far as the present investigations go, are composed of wood, bark (especially the cork tissue), spores and pollen grains, leaves, remains of fungi, and other fragments of vegetable tissues. Of these vegetable constituents of coal, the wood constitutes the bright coal, and the bark (especially the cork tissue), spores, pollen grains, leaves, fungal remains, and other small fragments of vegetable matter constitute the dull coal.

B. Coal from the Ominé colliery

Pl. XIV, Fig. 45 is a microphoto of a section of dull coal cut parallel to the bedding plane. The photograph shows the remains of some Cupressoxylon-type wood. This piece of wood is a small fragment; while the same type of wood, but of larger bulk, constitutes the bright coal in this coal mine.

Pl. XXIV, Fig. 119 shows a photograph of a section, cut parallel to the bedding plane of the seam, of a piece of the coal. There are shown a few sclerotia which are embedded in the dull coal, and the dark portion at the lower right corner shows a part of a section of a piece of bright coal. Also the cuticle, cork tissue, and spores are observed in the coal.

C. Coal from the Chiku-Ho coal-field

Pl. XXIV, Fig. 123 shows a microphoto of a section of a coniferous wood which was constituting a piece of bright coal from the Ōtsuji colliery, Fukuoka Prefecture. Due to the bad preservation further affinities of the wood could not be determined. Pl. XXIV, Fig. 118, shows a microphoto of a section, cut perpendicularly to the bedding plane of the seam, of a piece of dull coal from the same seam. Here we see two sections of sclerotium (s) very clearly. Pl. XXIV, Fig. 121 shows a microphoto of a section, cut parallel to the bedding plane of the seam, of another piece of coal from the same colliery. In this figure (c) shows a section of a piece of cork. The wall of cork cell was bright yellow under the microscope, and the cell cavities were filled with a brown colored homogeneous material. (s) in this figure is a sclerotium though it is not shown very clearly.

Pl. XIV, Fig. 40, (a) shows a microphoto of a section of a piece of dull coal from the Kankan seam in the Méo colliery, Fukuoka Prefecture, and Fig. 40, (b) shows a portion of Fig. 40, (a) with a higher magnification. As already mentioned above, in Fig. 40, (b), there are shown several pieces of leaves with well preserved cuticle and cutinized lamella, as well as cellulose lamella of epidermal cell wall, and some of parenchymatous cells of the mesophyll.

As also mentioned above, more than two kinds of spores were observed in the coal from several seams in this coal-field.

From what has been described above, we see that the coal from the Chiku-Ho coal-field, as far as my investigations go, are also composed of wood, bark, spores, leaves, remains of fungi, and other fragments of vegetable tissues.

D. Coal from the Takashima colliery

Vegetable components observed in the coal were as follows:

Wood. The big pieces of wood consist the bright coal and the small pieces the dull coal, combined with other material as in the other cases mentioned above.

Bark. Tissues of bark were observed in the dull coal, especially the cork tissue which was well preserved and generally bright yellow under the microscope.

Cuticle and cutinized tissue were observed, and some of them appeared together with the parenchymatous tissue.

Bright yellow thick-walled cells were observed in the dull coal. Such thick cell wall, the good preservation, and the irregular shape of these cells suggest that they are remains of stone cells.

In addition to the fungus remains, which were described in the other chapter, many sclerotia measuring 20–60 micra in their diameters, conidia, and isolated spores were observed.

E. Coal from the Yūbari colliery

Pl. XXIV, Fig. 122 shows a microphoto of a cross section of a coniferous wood which formed a piece of bright coal from the Yūbari colliery. It was very much compressed and deformed. The darker colored part in the figure was brown under the microscope, and the white part was bright yellow. The latter shows well preserved tracheid in cross sections. This bright yellow tracheid is a rare case met with in bituminous coal in the course of this investigation, in which the tracheids in bituminous coal were generally light or dark brown under the microscope.

Well developed cork tissue was observed in this coal too. It was mostly light brown under the microscope, but in some cases bright yellow.

Spores, sclerotia, and other remains of fungi were observed in the dull coal, together with the fragments of other plant tissues.

F. Coal from the Maizuru colliery

The vegetable tissue is well coalificated, but some remains of fungi, wood tissue, cork tissue, and cuticle were observed.

G. Coal from the Fu-chun colliery

Text Figure 19 shows a microphoto of a section,

Text Fig. 19. Microphoto of a section of coal from the Sakura seam, the Fu-chun colliery. w, fragment of a wood; s, sclerotium; b, fusaine. × 160.

cut perpendicularly to the bedding plane of the seam, of a piece of coal from the Sakura seam, the Fu-chun colliery. (w) in this figure shows a fragment of a wood, which was light brown under the microscope; (s) shows sclerotia which was reddish brown under the microscope; (b) shows a piece of fusaine which was almost black under the microscope. The other part consisted of fragments of vegetable tissue and spores.

Text Fig. 20. Two spore remains in coal from the Asahi seam, the Fu-chun colliery.

Text Fig. 20 shows sections of two different kinds of spores in compressed state in coal from the Asahi seam, the Fu-chun colliery. (a) measured about 40 μ in length and it had some sculptures on the wall; (b) which had smooth cell-wall measured about 50μ. Both spores were bright yellow under the microscope.

Text Fig. 21 shows a microphoto of a section of a piece of coal from the Asahi seam, the Fu-chun colliery. The irregular white stripes in this figure show some fibers which were bright yellow under the microscope.

Text Fig. 21. Microphoto of a section of coal from the Asahi seam, the Fu-chun colliery. × 160.

Several stone cells were observed in the coal, which were bright yellow and retained the properties of double refraction, though quite faintly.

In addition to those mentioned above, there were observed larger pieces of wood constituting bright coal, and cuticle, cork tissue, and other fragments of vegetable tissue constituting dull coal.

H. Lignite from the Kashū colliery

Many twigs and wood tissues are preserved in good condition. Pl. XIII, Fig. 33 shows an example, in which we find two cross sections of young twigs; one of them has well preserved large stone cells in its pith.

A section of an angiospermous leaf was found. The transverse diameter of the palisade cell measured about 60 micra. It is to be noted that the guard cells of the stomata were in a better preservation than the other tissue. They appear always in pairs, the longer diameter being about 70 micra. These guard cells, when they were detached from the other tissue of the leaf, were mistakable for some kind of spores. Such detached guard cells have also been met with in coal from Nagakura.

Sclerotia also were observed in the lignite.

In addition, cuticle, bark, spores, and some leaves about 700 micra wide and about 50 micra thick in cross section were observed. The latter are probably to be identified with those of certain mosses.

I. Lignite from Aichi coal-field

The principal constituent of the lignite from the Aichi coal-field is coniferous wood. The wood is embedded in the matrix, as is shown in Pl. XII, Fig. 22 (w).

a. Lignitoid. Lignitoids in the lignite, as already stated in the descriptions in chapters III and V, mostly belong to the conifer, and occur in sizes varying from very small fragments to massive wood of very old plants. They represent parts not only of stems, but also of roots. Text Fig. 22 shows some examples of those lignitoids.

The representatives of angiospermous wood are very few in number and probably in bulk, moreover they are usually embedded in the matrix as small fragments.

About fifty or more pieces of wood from the Aichi coal-field were examined. Some of them were very much compressed and deformed, so that their taxonomic identification was exceedingly difficult, but in about thirty of them some details of the structure of the tissue could be described with certainty, though not in every case was it possible for the writer to determine the affinities. About ten of them belonged to the Sequoioxylon type of wood, twenty to the *Cupressoxylon nagakudéense* type, few others to other Cupressoxylon, and only one of them to an angiospermous wood resembling that of *Quercus*.

b. Matrix. The matrix (or dull coal) consists of several kinds of vegetable matter, such as cuticle, cork tissue, leaves, small fragments of wood, cryptogamic spores, pollen grains, remains of mosses, etc.

Pl. XXIII, Fig. 113 is a microphoto of a section of a lignite from Nagakudé, cut perpendicularly to the bedding plane. In the center of the photograph there is a large sclerotium, and on both sides of it

Text Fig. 22. Photographs of four pieces of wood in lignite from the Aichi coal-field. a, *Sequoioxylon hondoense* × 1/5; b, *Cupressoxylon nagakudéense* × 2/3; c_1, cross section of *Cupressoxylon* sp., c_2, the side view of the same wood as c_1. ca. × 1/3.

smaller ones are seen. The stripes running horizontally are to be taken to be sections of leaves, probably those of mosses. The rest consists of small fragments of plant tissue or cells.

Pl. XXII, Fig. 95 shows another 'perpendicular section' of the lignite from the same locality. Here is shown prominently a cross

section of the stem of a moss of which descriptions have already been given. The waving stripe below the stalk (M) is a part of a longitudinal section of another stalk, and (L) in this figure presents cross sections of leaves of certain mosses.

Pl. XXIII, Fig. 111 is a 'parallel section' of a lignite from the Takahari colliery. (s) is a section of a sclerotium like that shown in Fig. 113. On the right side of the sclerotium there is seen a spindle-shaped body (d), identified as a diatom.

Pl. XXIII, Fig. 105 shows another part of the same section as that from which Fig. 111 was taken, highly magnified. (P) is the same kind of a pollen grain as the one mentioned above. It is ellipsoidal in shape and has a border running longitudinally. Similar pollen grains were found in the coal from Ibaraki and Fukushima. There are several simple conidia and small isolated cells like spores of fungi.

Pl. XXIII, Fig. 108 is another part of the same section, and in this (d) shows a diatom.

Several fragments of an angiospermous wood were observed in the specimen from Takahari, Nagakudé, and other collieries.

There is a fossil cone, *Pinites Fujiii*, from the Séto seam, though no Pityoxylon-type wood has yet been found in the lignite as far as examined.

In addition, many fragments of bark, leaves, cuticle, and cork tissue were met with.

From what has been described above, the vegetable components of the lignite from the Aichi coal-field may be enumerated as follows :

1 Wood.
   a Coniferous wood.
   b Angiospermous wood.
2 Bark, especially cork tissue and the bast.
3 Fragments of leaves.
4 Cuticle and cutinized epidermal tissue.
5 A cone of a pine.
6 Mosses.
7 Spores and pollen grains.
8 Conidia, sclerotia, and some remains of fungal hyphae.
9 Diatoms and fragements of *Oedogonium* sp.
10 Fragments of vegetable tissue, the histological nature of which can not be determined.

J. Lignite from the Tōnokura colliery

In addition to woody tissues, there are found in the matrix, spores, tetrahedral pollen grains measuring about 40 micra or more in diameter, cutinized portion of epidermis, some conidia, and some remains of fungal hyphae about 5 micra in transverse diameter.

The study of lignite and coal from all other collieries showed that the chief vegetable constituents are alike.

VII. Summary and conclusion

1 Bituminous coal from twenty-two different seams and brown coal and lignite from seventeen different localities were investigated, three specimens of the bituminous coal being obtained from each seam, one each from the upper, middle, and lower layers of the seam.

2 Materials, after necessary treatment, were as a rule embedded in celloidin, and microtome sections were made; sometimes hand sections were used, while the grinding method was adopted in only one case.

3 Plant tissues in lignite and coal were microscopically studied with ordinary as well as with polarized light, and also certain chemical tests were applied.

4 Several kinds of cell walls — cutinized, suberized, lignified, chitinous, and parenchymatous cell walls — were investigated in all specimens of lignite, brown coal, and some bituminous coal. The cutinized cell wall and the chitinous cell wall are the two most resistant vegetable elements, consequently they persist for a long time, while parenchymatous cell walls have often been destroyed and disappeared.

5 The lignified cell walls in the several different degrees of coalification showed different degrees of double refraction, the latter property being gradually lost as the coalification advanced. Keeping pace with this change in the cell wall, the cellulose is gradually abstracted from the wall. From this we may conclude that one of the essential processes in the early part of coalification is the abstraction of cellulose from the cell wall, in addition to other chemical changes taking place during the process.

6 Parenchymatous cells and tissue are sometimes in an admirable state of preservation, the morphological remains of nuclei and other cell elements being recognizable.

7 The bright coal, the dull coal, and the fusaine in bituminous coal correspond to the lignitoid of JEFFREY, the matrix, and the charred material in lignite.

8 More than six kinds of coniferous wood, two kinds of small branches of conifers, two kinds of angiospermous wood, a pine cone, an aerial stem of a moss of the *Polytrichum* type, leaves of mosses, more than three kinds of angiospermous pollen grains, one kind of gymnospermous pollen grain, more than two kinds of fern spores, a kind of diatom, a kind of alga, and several kinds of fungi were observed, mostly in lignite, but some in bituminous coal.

9 Vegetable constituents in several seams in different localities were described.

10 From investigations of the vegetable materials in Japanese lignite, brown coal, and bituminous coal, the writer has come to the conclusion that the vegetable constituents are nearly of the same kind, and that the chief mass of Japanese coal is composed of coniferous wood.

11 The writer holds the view that the coal was formed of aquaeous accumulations and transported products. From the excellent preservation of the morphological cell elements, together with the preservation of cellulose and other constituents of cell walls, and the absence of severe attacks of microorganisms in the main mass of coal-forming material, it is also maintained that the place where the accumulation took place was sterile against such microorganisms, so that microorganisms can not be taken for coal-forming agencies, as is maintained by some authors.

The expense of carrying out this study was partly defrayed out of a grant from the Department of Education, to the authorities of which the writer wishes to express her best thanks. To Prof. K. FUJII the writer wishes to express her indebtedness and gratitude for his valuable advice and various criticisms throughout the work; and her hearty thanks are also due to Prof. E. C. JEFFREY of Harvard University, Cambridge Mass., U. S. A. She is also greatly indebted to Prof. K. SHIBATA and Prof. B. HAYATA for their kind advice. Further acknowledgments are due to those gentlemen who placed the materials for the present study at her disposal.

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VIII Bibliography

Ambron, H. (1888) Ueber das optische Verhalten der Cuticula und der verkorkten Membranen. Ber. d. Deutsch. Bot. Ges. Bd. 6, p. 266.

Balfour, J. W. (1857) On certain vegetable organisms found in coal from Fordel. Trans. Royal Soc. Edinburgh. vol. 21, pp. 187-195. (After Stopes and Wheeler. 1918.)

Bertrand, C. E. and Renault, B. (1892) Pila bibractensis et le Boghead d'Autun. Bull. soc. d' hist. nat. d' Autun, 5, p. 159.

Dippel, L. (1898) Das Mikroskop und seine Anwendung. 2. Teil. Anwendung des Mikroskops auf die Histologie der Gewächse. 2. Aufl. Braunschweig.

Dowson, J. W. (1870) On spore cases in coal. Amer. Jour. Sci. and Arts. vol. 1. 3rd. Ser. pp. 265-273.

Felix, J. (1894) Studien über fossile Pilze. Zeitsch. d. Deutsch. Geolog. Ges. Jahrg. 1894, Heft 1.

Fuchs, W. (1926) Die Chemie des Lignins. Berlin.

Fischer, F. und Schrader, H. (1922) Entstehung und chemische Struktur der Kohle. 2. Aufl. Essen.

Frey, A. (1926) Die submikroskopische Struktur der Zellmembranen. Eine polarizationsoptische Studie zum Nachweis der Richtigkeit der Mizellartheorie. Jahrb. f. wiss. Bot. Bd. 65, Heft 2, pp. 195-223.

Fujii, K. (1910) Some remarks on the Cretaceous fossil flora and the causes of extinction. Bot. Mag. Tokyo. vol. 24, pp. 199-204.

Géneau de Lamerlière, M. L. (1903) Recherches sur quelques réactions des membranes lignifiées. Rev. gen. de bot. t. 15, pp. 149-159, 221-234.

Jeffrey, E. C. (1909) On the nature of so-called algal boghead coal. Rhodra. vol. 11, p. 61.

——— (1915) The mode of the origin of coal. The Journ. of Geology, vol. 23, No. 3.

——— (1924) The origin and organization of coal. Memoirs. Amer. Acad. Arts and Sci. vol. 15, No. 1.

——— (1925) Coal and civilization. New York.

——and Chrysler, M. A. (1906) The lignite of Brandon. The fifth report. Vermont State Geologist.

Karsten, C. J. B. (1826) Untersuchung über die kohligen Substanzen des Mineralreiches und über die Zusammensetzung der in der Preussischen Monarchie vorkommenden Steinkohlen. Archiv Bergbau Bd. 12, pp. 3-244.

König, J. und Rump, E. (1914) Chemie und Struktur der Pflanzenzellmembran. Berlin.

Kuntze, O. (1884) Phytogeogenesis. Leipzig.

Kürschner, K. (1925) Zur Chemie der Ligninkörper. Stuttgart.

Mäule, C. (1900) Das Verhalten verholzter Membranen gegen Kaliumpermanganat, eine Holzreaktion neuer Art. Fünfstücks Beitr. wiss. Bot., Bd. 4.

Potonié, H. (1920) Die Entstehung der Steinkohle. 6. Aufl. Berlin.

Potonié, R. (1920) Der mikrochemische Nachweis fossiler kutinisierter und verholzter Zellwände sowie fossiler Zellulose und seine Bedeutung für die Geologie der Kohle. Jahrb. der Preus. Geolog. Landesanstalt. Bd. 41, Teil 1, Heft 1.

——— (1924) Einführung in die allgemeine Kohlenpetrographie. Berlin.

REISS, K. (1907) Untersuchung über fossile Hölzer aus Japan. Dissertation. Rostock.

RENAULT, M. B. (1895) Note sur les cuticules de Tovarkovo. Bull. de la soc. d'hist. nat. d'Autun, t. 8.

ROGERS, H. D. (1858) The geology of Pennsylvania, a government survey, with a general view of the geology of the United States. Essays on the coal-formation and its fossils, and a description of the coal-fields of North America and Great Britain. Edinburgh and London. Philadelphia.

STOPES, M. C. and FUJII, K. (1910) Studies on the structure and affinities of Cretaceous plants. Phil. Trans. Roy. Soc. London, Ser. B, vol. 201, pp. 1-90.

STOPES, M. C. and KERSHAW, E. M. (1910) Anatomy of Cretaceous pine leaves. Ann. Bot. vol. 24, p. 395.

STOPES, M. C. and WHEELER, R. V. (1918) Monograph on the constitution of coal. London.

SEWARD, A. C. (1919) Fossil plants, vol. 4. London.

SUZUKI, Y. (1910) On the structure and affinities of two conifers and a new fungus from the Upper Cretaceous of Hokkaido (Yezo). Bot. Mag. Tokyo, vol. 24, pp. 181-196.

THIESSEN, R. (1920) Compilation and composition of bituminous coals. Journ. Geology. vol. 28, pp. 185-209.

WHITE, D. and THIESSEN, R. (1913) The origin of coal. Bureau of Mines Bulletin 38, Department of the Interior, U.S.A.

YASUI, K. (1917) A fossil wood of *Sequoia* from the Tertiary of Japan. Ann. Bot. vol. 31, No. 12, pp. 101-106.

——— (1925) On the alteration of the cell wall in the process of coalification, with special reference to the optical property of the wall. Bot. Mag. Tokyo, vol. 39, No. 467, pp. 280-290,

——— (1926) Description of internal structure of remains of a Tertiary moss. Bot. Mag. Tokyo, vol. 40, No. 469, pp. 15-18.

YOSHIWARA, S. (1898) List of Tertiary fossils of Japan (Japanese). Journ. Geol. Soc. Tokyo. vol. 5, Nos. 54-57, Appendices.

YOSHIWARA, S. (1900) List of Cainozoic fossils of Japan. Supplement I. (Japanese). Journ. Geol. Soc. Tokyo, vol. 7, No. 81, Appendix.

ZEILLER, R. (1882) Observations sur quelques cuticules fossiles. Ann. sci. nat. Bot. 6^e^ sér. t. 13, pp. 213-238.

IX. Explanation of Plates

All figures, except Figs. 46, 47, and 80-82, are microphotographs.

Plate IX

Fig. 1. A radial section of a coniferous wood, showing ray tissue in which the cellular structure is well preserved; n, nucleus; r, resinous ray cell. ×280.

Fig. 2. A radial section of wood of *Cryptomeria japonica*, showing ray tissue; n, nucleus of the ray cell. ×280.

Fig. 3. A 'parallel section' of coal, from the middle part of a seam in the Nagakura colliery, showing a part of the mesophyll of an angiospermous leaf. ×98.

Fig. 4. A 'parallel section' of lignite from Kaigaké. In the middle of the left part of the figure is seen a piece of a section of an angiospermous wood. ×49.

Fig. 5. A cross section of wood in lignite from Miyagi Prefecture. Prominent black spots in the figure represent resin cells (r), and the darker zigzag stripes ray tissue. ×80.

Fig. 6. A cross section of wood in lignite from Miyagi Prefecture. In the upper and lower parts of the figure, not very much compressed summer wood and in the middle part very much compressed spring wood are seen. Resin cells seen in both spring and summer wood. ×100.

Fig. 7. A cross section of wood in lignite from the Doi colliery. White squares show the not much compressed summer tracheids; surrounding them strongly compressed darker colored tracheids seen; r, resin cell. ×80.

Fig. 8. A cross section of wood of Sequoioxylon type in lignite from Miyagi Prefecture. The wood suffered from compression in the tangential direction, so that the annual ring became wavy; the black lines across the figure are ray tissues; r, resin cell. ×100.

Plate X

Fig. 9. A radial section of wood of *Cryptomeria japonica*, seen with crossed nicols, the longitudinal axis of tracheids being placed diagonally to the vibration direction of the nicols. ×330.

Fig. 10. A longitudinal section of wood, possibly a fossil cryptomerian wood, in lignite, seen with crossed nicols, the orientation of the longitudinal axis of tracheids being the same as that of the Fig. 9. ×330.

Fig. 11. A cross section of a coniferous wood in lignite, seen with ordinary illumination. ×156.

Fig. 12. The same section as that of which the photograph in Fig. 11 was taken, seen with a higher magnification and with crossed nicols, the radial wall of the tracheids being orientated parallel to the vibration direction of the polarizer. ×420.

Fig. 13. A longitudinal section of a coniferous wood in lignite, seen with ordinary illumination. ×420.

Fig. 14. The same section as that of which the photograph in Fig. 13 was taken, seen with crossed nicols, the longitudinal axis of the tracheids being orientated diagonally to the vibration axes of the nicols. ×420.

Plate XI

Fig. 15. A cross section of wood in lignite from Séto; black lines show ray tissues, the spring wood suffered from compession, but summer wood not so much, though the tracheids are much deformed. ×80.

Fig. 16. A part of Fig. 15, highly magnified, showing tracheids.

Fig. 17. A part of the section from which the photograph in Fig. 15 was taken, shown with a higher magnification, and with crossed nicols. ×250.

Fig. 18. A cross section of a coniferous wood, probably of root nature, in bituminous coal from Nagakura. ×80.

Fig. 19. A cross section of a coniferous wood in bituminous coal from the lower part of a seam in the Ibaraki colliery. Tissue much deformed, but still showing the cell cavities of tracheids and resin cells. ×49.

Fig. 20. A cross section of wood in bituminous coal from the lower part of a seam in the Nagakura colliery. Tissue very much deformed; black wavy stripes are resinous ray tissues. ×100.

Fig. 21. A cross section of wood in brown coal from the Shirakawa colliery, Mié Prefecture. Black wavy stripes represent the resinous ray tissues. ×100.

Fig. 22. A 'perpendicular section' of a lignite from the Takahari colliery in the Aichi coal-field. Darker part shows matrix or dull coal; w, wood. ×8.

Plate XII

Fig. 23. A 'perpendicular section' of coal from the middle part of a seam in the Nagakura colliery. Several white lines, running across the figure show sections of epidermal tissue. ×80.

Fig. 24. A 'parallel section' of a piece of coal from the middle part of a seam in the Nagakura colliery. A piece of wood is shown in the upper part of the figure, and pieces of cork tissue, C_1 and C_2, seen lying across about the middle part. ×48.

Fig. 25. A part of the cork tissue in Fig. 24, highly magnified. ×400.

Fig. 26. A 'perpendicular section' of brown coal from the Hazama colliery, Mié Prefecture. Cork tissue and serrate epidermal tissue seen. ×100.

Fig. 27. A part of cork tissue in Fig. 26, shown highly magnified.

Fig. 28. A 'parallel section' of a brown coal from the Hirako colliery. A tangential section of cork tissue is shown. ×80.

Fig. 29. A section of coal from the lower part of the Nagakura seam. A cross section of a twig (c) with cork tissue is shown. ×80.

Fig. 30. A part of Fig. 29, highly magnified. ×500.

Plate XIII

Fig. 31. A cross section of a twig in lignite from the Tayama colliery; (s), well preserved stone cells. ×80.

Fig. 32. Stone cells and surrounding tissue in Fig. 31, highly magnified. ×500.

Fig. 33. A 'perpendicular section' of lignite from the Kashū colliery, Hyōgo Prefecture. Two cross sections of young twigs seen. ×80.

Fig. 34. A cross section of wood of a coniferous twig in lignite from the Kashū colliery, including the pith, with several stone cells in it. ×80.

Fig. 35. A longitudinal section of the same specimen, from which the photograph in Fig. 34 was taken. Large stone cells in the pith are shown. ×80.

Fig. 36. A radial longitudinal section through the axis of a twig in lignite from the Hirako colliery. Large stone cells in the pith are shown. ×80.

Fig. 37. A longitudinal section through the axis of the stem of *Cryptomeria japonica*. Large stone cells are shown. ×80.

Fig. 38. A longitudinal section of a part of the same twig as that of Fig. 34; in the left part of the figure, bast fibers and stone cells in bast are seen, the right part of the figure is occupied by the wood. ×80.

Plate XIV

Fig. 39. A part of the same section from which Pl. XII, Fig. 23 was taken, highly magnified; the white serrate stripes are transverse sections of the epidermis.

Fig. 40. A section of a piece of bituminous coal from the Méo colliery, Fukuoka Prefecture. Sections of leaves are seen. a, ×80; b, ×160.

Fig. 41. A part of the bast of the fossil twig shown in Pl. XIII, Fig. 38, highly magnified; s, stone cell. ×120.

Fig. 42. A longitudinal section of a part of the bast of *Cryptomeria japonica*. Observe the similarity between this figure and the preceding figure; s, stone cell. ×120.

Fig. 43. A cross section of a twig in lignite from the Tayama colliery; the small white bars in the bast represent bast fibers (f). ×80.

Fig. 44. A part of Fig. 43; cross section of bast fibers (f) shown ×580.

Fig. 45. A 'parallel section' of bituminous coal from the Ōminé colliery, a tangential section of deformed tracheidal tissue shown; the cell walls of ray cells (r) not suffered so much as the tracheids. ×250.

Plate XV

Fig. 46. Fusaine in lignite from the Aichi coal-field. ca. ×1.

Fig. 47. A part of a partially charred wood which occurred associated with the fusaine shown in Fig. 40. ca. ×1.

Plate XVI

Fig. 48. A cross section of wood of *Cupressoxylon nagakudéense* sp. nov. from the Nagakudé colliery, Aichi Prefecture. ×80.

Fig. 49. A radial section of the same wood as that shown in Fig. 48. ×80.
Fig. 50. A tangential section of the wood shown in Fig. 48. ×80.
Fig. 51. A part of the same wood as that of Fig. 48; bast fibers shown clearly. ×80.
Fig. 52. A part of the same wood as that of Fig. 48; large stone cells in pith are shown. ×80.
Fig. 53. A *Cupressoxylon* from the Ōkusa colliery; cross section. ×80.
Fig. 54. The same; radial section. ×80.
Fig. 55. The same; tangential section. ×80.

Plate XVII

Fig. 56. A coniferous wood form the Jurassic, Manchuria; cross section. ×80.
Fig. 57. The same; radial section. ×80.
Fig. 58. The same; tangential section. ×80.
Fig. 59. *Sequoioxylon hondoense;* cross section; lying across the middle of the figure, traumatic resin canals seen. ×80.
Fig. 60. The same; longitudinal section; a longitudinal section of a resin canal seen in the middle. ×80.
Fig. 61. The same; tangential section; terminal pits visible on the summer tracheids. ×80.
Fig. 62. The same; radial section. ×80.
Fig. 63. A part of Fig. 59 including resin canals, highly magnified.

Plate XVIII

Fig. 64. *Cupressoxylon kōzōjiense* sp. nov.; radial section. ×80.
Fig. 65. The same; radial section. ×80.
Fig. 66. The same; tangential section. ×80.
Fig. 67. A part of Fig. 65, highly magnified.
Fig. 68. *Sequoioxylon miyagiense*, sp. nov.; cross section. ×80.
Fig. 69. The same; radial section. ×80.
Fig. 70. The same; a part of ray tissue in Fig. 69, highly magnified.
Fig. 71. The same; tangential section of the spring wood. ×80.
Fig. 72. The same; cross section of a macerated material; (R), traumatic resin canal. ×80.
Fig. 73. The same, showing terminal pits in the summer tracheids. ×80.

Plate XIX

Fig. 74. An angiospermous wood from Nagano Prefecture; cross section. ×80.
Fig. 75. The same; radial section, some fungus with conidia seen in it. ×80.
Fig. 76. The same; tangential section. ×80.
Fig. 77. The same; two conidia in the tissue shown with a higher magnification than those in Fig. 75.
Fig. 78. *Dryoxylon chitaense;* tangential section, large compound ray tissue seen in the central part, on both sides of the latter large vessels seen. ×80.
Fig. 79. The same; tangential section of wood, especially showing the region of wood fibers. ×80.

Plate XX

Fig. 80. *Pinites Fujiii*, sp. nov.; the basal view of the cone. ca. ×1.

Fig. 81. The same; the side view. ca. ×1.

Fig. 82. The same; the top view, slightly enlarged.

Fig. 83. The same; cross section of the cone axis. Central darker part shows the pith, and the outer lighter parts, the primary xylem and secondary tissue. ×16.

Fig. 84. The same; a part of the tangential section of the cone axis, including primary xylem and the scale gaps. ×16.

Fig. 85. The same; a part of the cross section of the axis of the cone, showing the primary xylem; c, resin canal. ×80.

Fig. 86. A part of a cross section of the cone axis of *Pinus Thunbergii*, showing a part of the pith, the primary xylem, and the early developed part of the secondary tissue; c, resin canal. ×80.

Fig. 87. A part of Fig. 83 highly magnified; upper part shows the tissue of pith, lower part, compressed wood; p, beginning of protoxylem; c, resin canal. ×140.

Plate XXI

Fig. 88. *Pinites Fujiii*, sp. nov.; cross section of the cone scale, of which about one half is shown. ×8.

Fig. 89. The same; a part of the cross section of a scale, including two vascular bundles in it; v, vascular bundle. ×30.

Fig. 90. The same; a part of longitudinal section of a scale; c, resin canal. ×30.

Fig. 91. The same; a part of the cross section of a scale, showing a resin canal. ×580.

Fig. 92. The same; upper part of the cross section of a scale especially showing sclerotic tissue in the upper side of the scale; a vascular bundle and stone cells among parenchymatous cells seen; v, vascular bundle; c, resin canal. ×40.

Fig. 93. A part of Fig. 89 is shown highly magnified; r, resin canal. ×60.

Fig. 94. A part of the cross section of a cone scale of *Pinus Thunbergii;* v, vascular bundle; r, resin canal. ×30.

Plate XXII

Fig. 95. A 'perpendicular section' of lignite from Aichi coal-field; (M), cross section of an aerial stem of a moss, *Polytrichites aichiense* nom. nov.; (L), a cross section of a leaf of a moss. ×48.

Fig. 96. *Polytrichites aichiense ;* a part of the stem highly magnified; a, xylem; b, endodermis. ×260.

Fig. 97. A cross section of a moss leaf. ×100.

Fig. 98. *Polytrichites aichiense*; cross section of the stem, slightly oblique; x, xylem. ×260.

Fig. 99. A cross section of the aerial stem of *Polytrichum commune*; S, base of leaf; l, leaf trace. ×48.

Fig. 100. *Polytrichites aichiense* ; cross section of the stem, somewhat oblique; S, base of a leaf. ×160.

Fig. 101. A cross section of a moss leaf. ×100.

Fig. 102. Another part of the specimen from which Fig. 100 was taken; l, leaf trace. ×160.

Fig. 103. Microphoto of the same specimen from which Fig. 93 was taken; photograph taken with crossed nicols. ×260.

Plate XXIII

Fig. 104. A tetrad pollen grain in lignite from Takahari, Aichi Prefecture. ×750.

Fig. 105. A pollen grain (p) in lignite from Takahari, Aichi Prefecture. ×430.

Fig. 106. A pollen grain in coal from Nagakura, Fukushima Prefecture. ×430.

Fig. 107. A fern spore in lignite from Takahari, Aichi Prefecture. ×750.

Fig. 108. A diatom in lignite from Takahari, Aichi Prefecture. ×430.

Fig. 109. A diatom in lignite from Takahari, Aichi Prefecture. ×430.

Fig. 110. Fern spores in coal from Nagakura, Fukushima Prefecture. ×560.

Fig. 111. A cross section of a sclerotium (s), and a diatom (d) in lignite from Takahari, Aichi Prefecture. ×160.

Fig. 112. Remains of a certain fungus in coal from Ōminé, Yamaguchi Prefecture ×250.

Fig. 113. A 'perpendicular section' of lignite from Nagakudé; sclerotia (s), moss leaves, and spores seen. ×49.

Fig. 114. A 'parallel section' of lignite from Aichi, a group of sclerotia and fungal hyphae seen. ×400.

Fig. 115. A tangential section of a piece of bark of *Cunninghamia lanceolata* Lamb. with a fungus; conidia-like structures seen in parenchymatous cells of the bark. ×80.

Plate XXIV

Fig. 116. A 'parallel section' of coal from the Nagakura colliery, roundish black part at the center of the figure represents a sclerotium, smaller irregular black patches being the hyphae.

Fig. 117. Fungus remains in bituminous coal from Ju-Hasshaku seam, the Takashima colliery; a, mass of hyphae in the matrix. ×80; b, conidia in the matrix. ×280; c, isolated spores and conidia in the matrix. ×400. d, an isolated spore highly magnified.

Fig. 118. A 'perpendicular section' of a piece of dull coal from the Ōtsuji colliery, Fukuoka Prefecture. In the right side of the figure two sclerotia (s) seen. ×80.

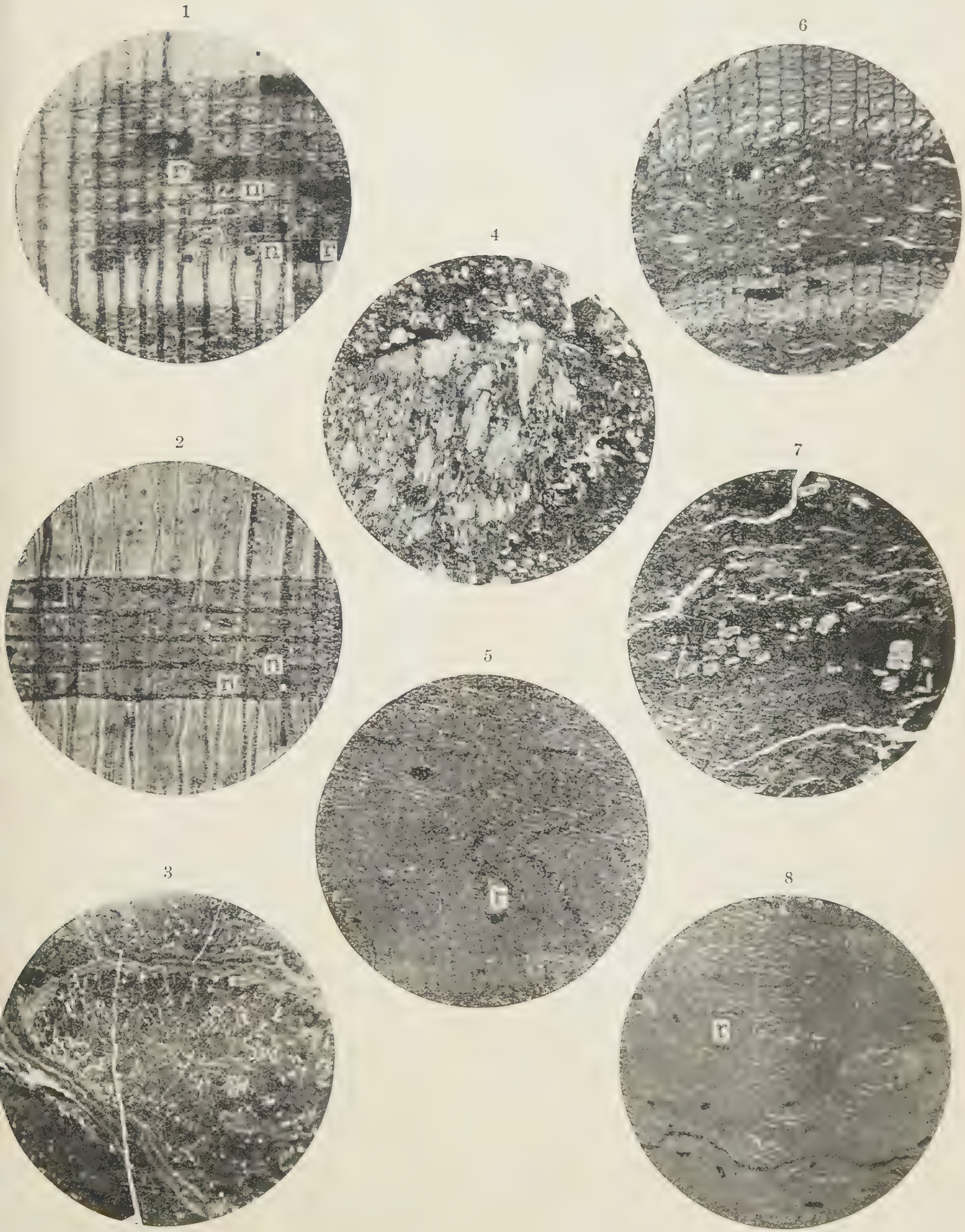
Fig. 119. A 'parallel section' of coal from the Ōminé colliery, Yamaguchi Prefecture; in the matrix sclerotia (s) seen; the dark part in the lower right corner of the figure shows a part of bright coal. ×160.

Fig. 120. A ' perpendicular section ' of a piece of dull coal from the Yūbari colliery, Hokkaido; sclerotia seen; white bars in the figure mostly show spores. ×160.

Fig. 121. A ' perpendicular section ' of a piece of dull coal from the Otsuji colliery, Fukuoka Prefecture; cork tissue (c) and a sclerotium (s) seen. ×160.

Fig. 122. A ' perpendicular section ' of a piece of bright coal from the Yūbari colliery, Hokaido; patches of white squares show cross sections of well preserved tracheidal cells. ×160.

Fig. 123. A 'perpendicuar section' of a piece of bright coal from the Ōtsuji colliery, Fukuoka Prefecture. ×80.



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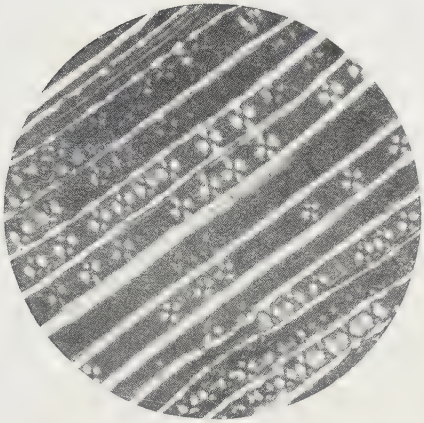

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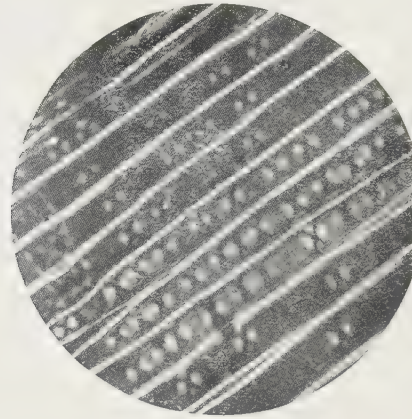

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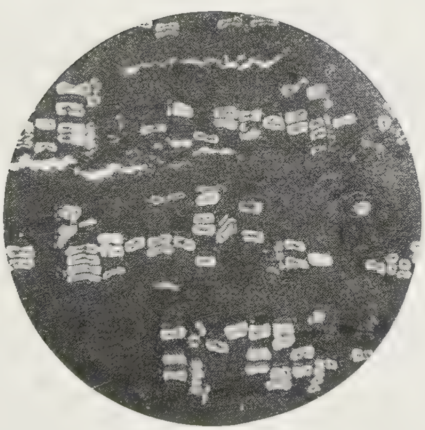

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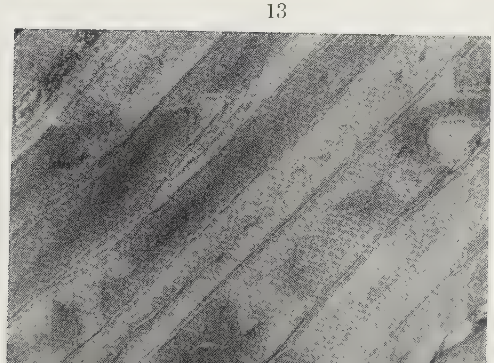

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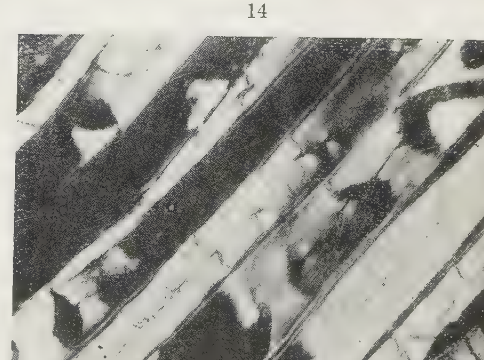

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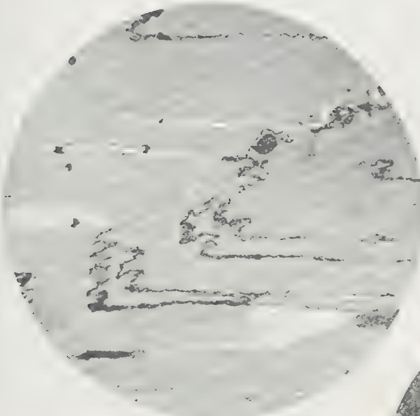

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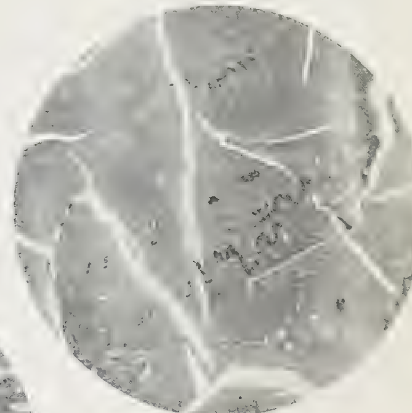

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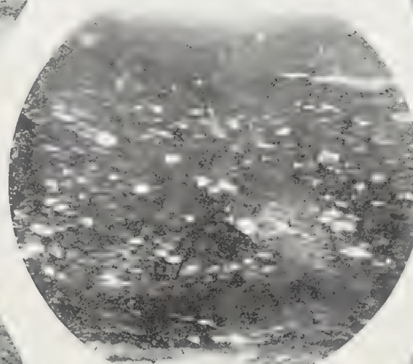

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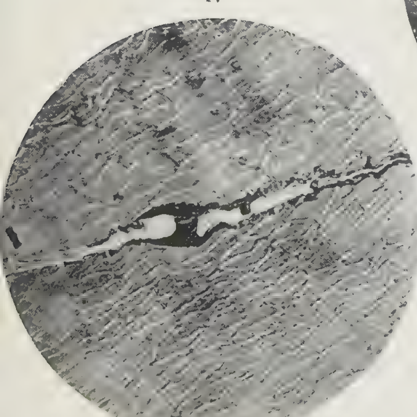

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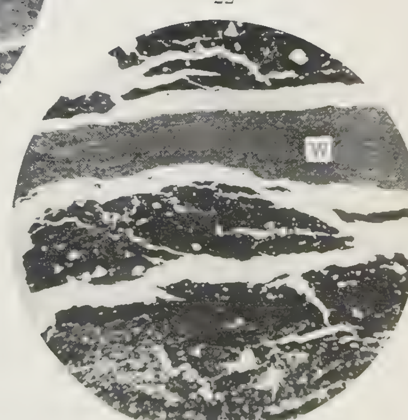

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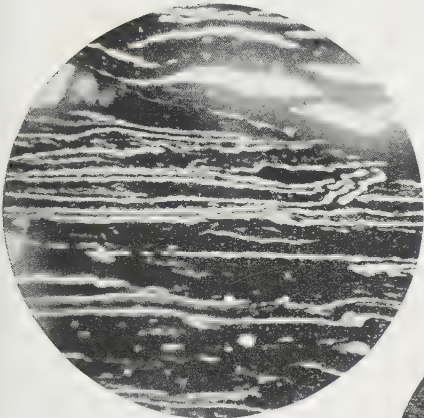

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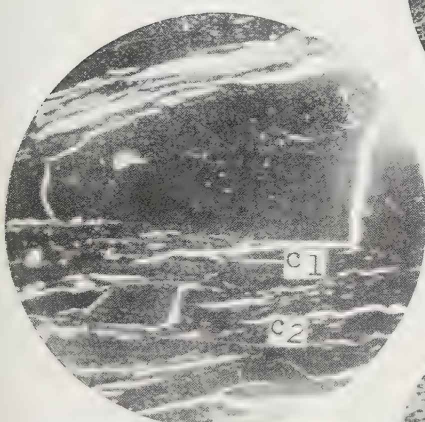

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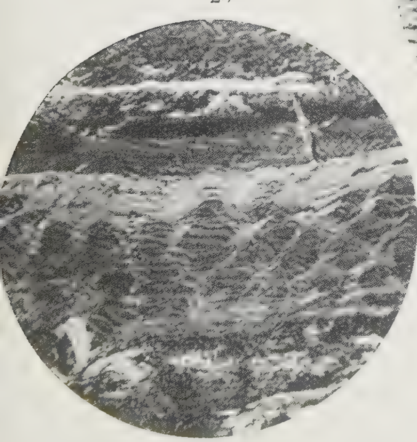

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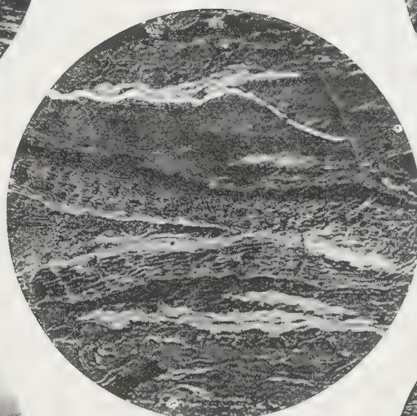

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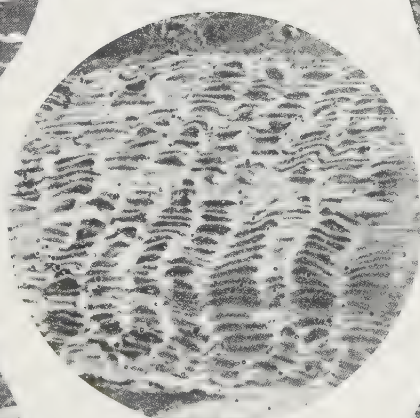

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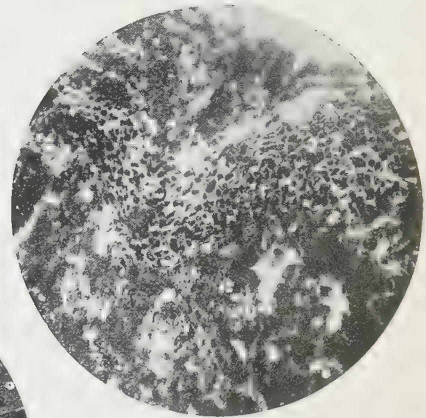

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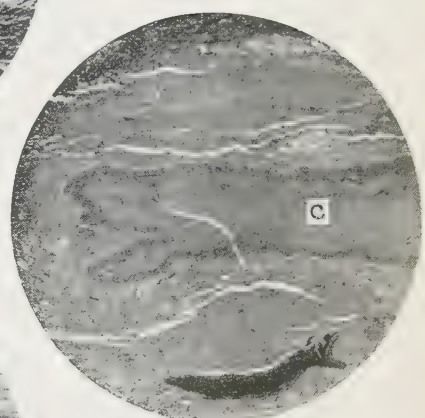

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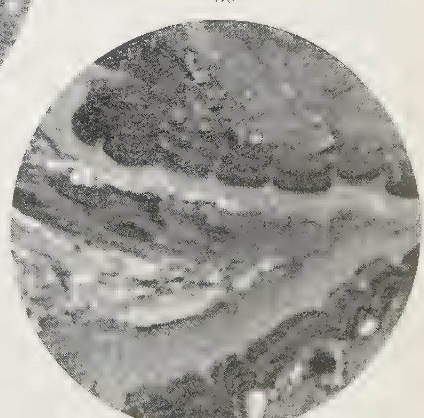

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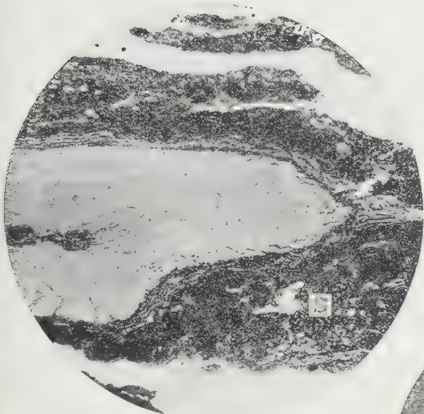

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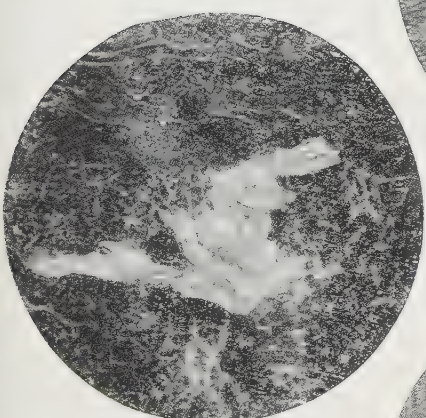

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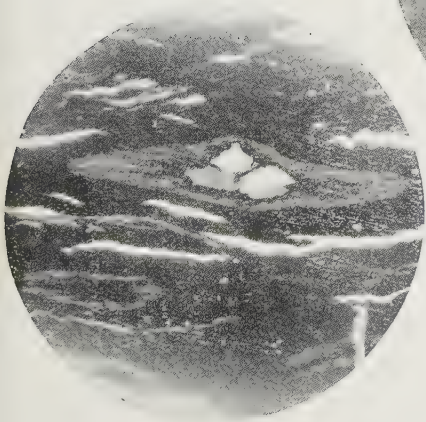

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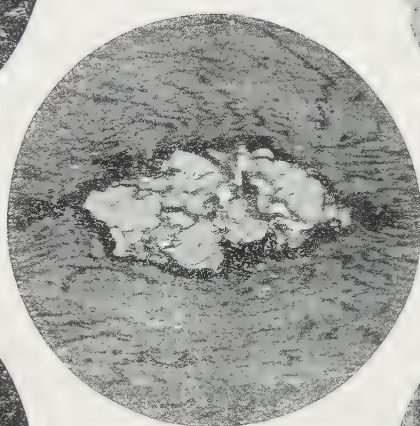

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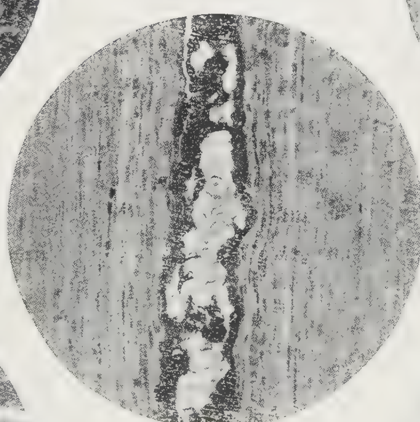

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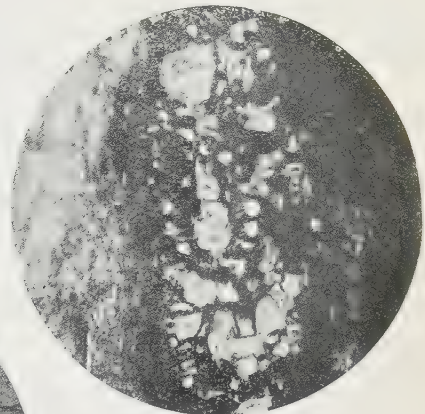

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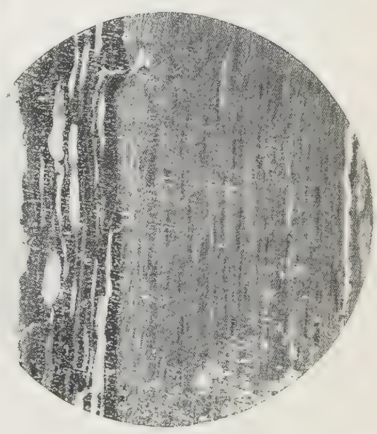

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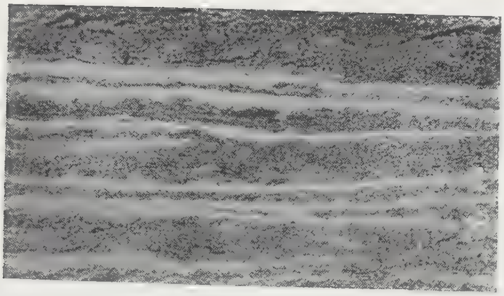

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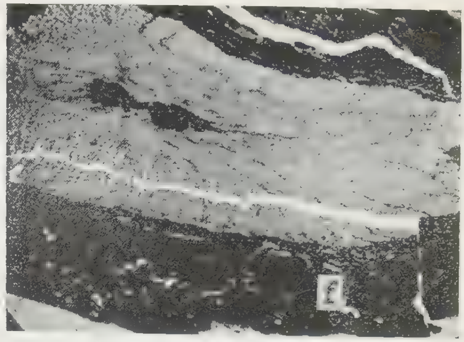

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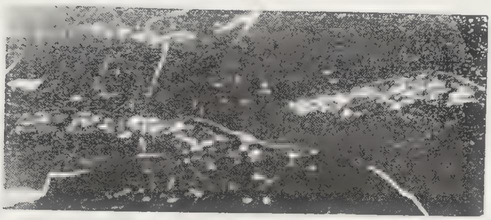

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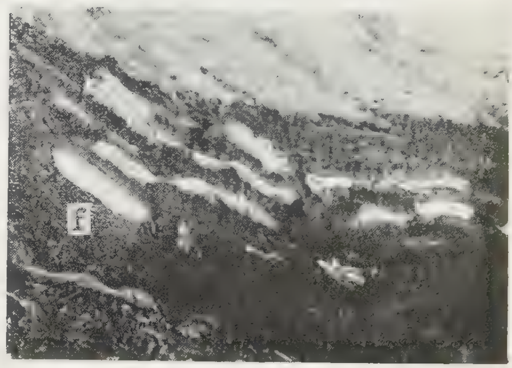

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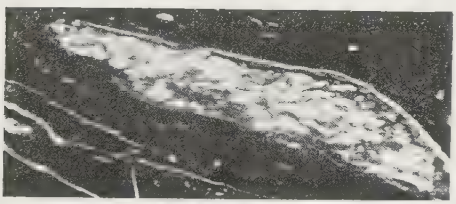

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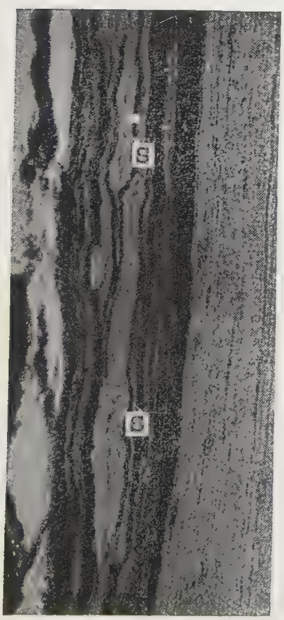

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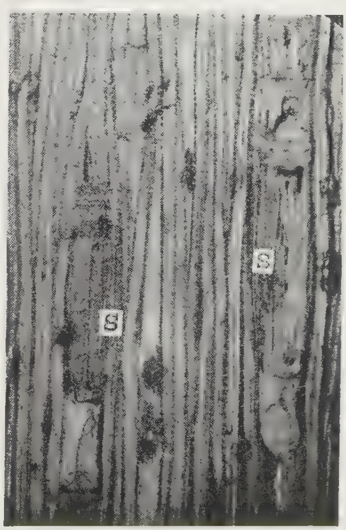

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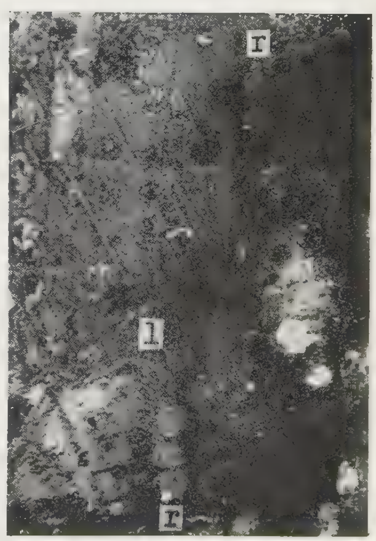

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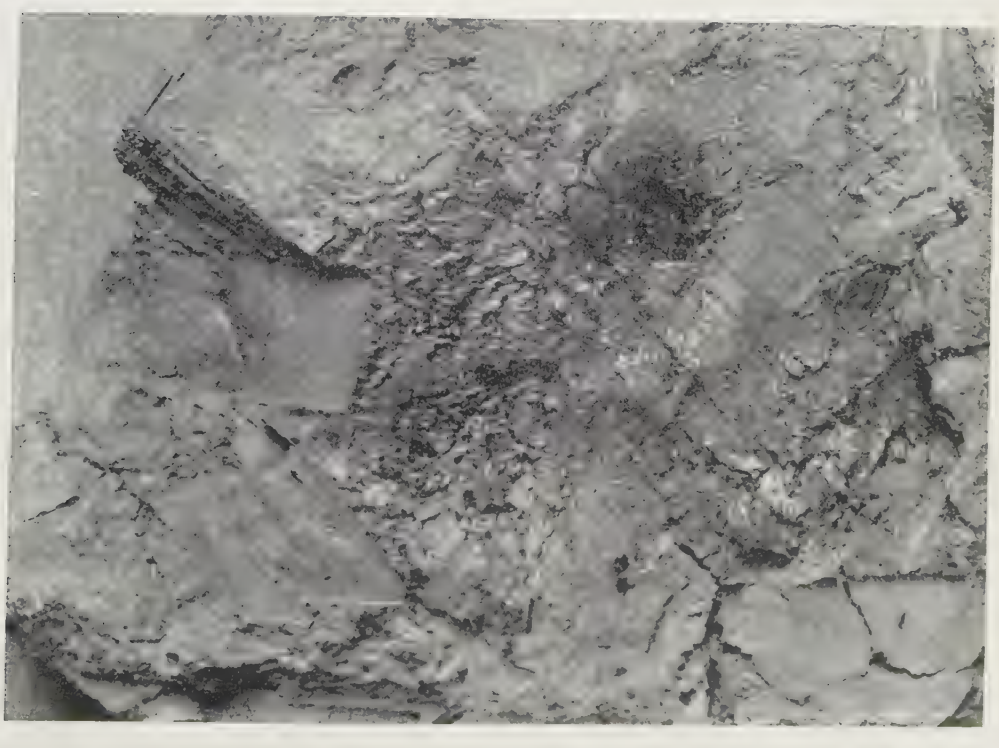

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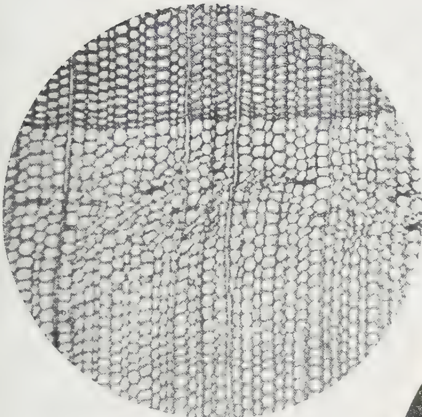

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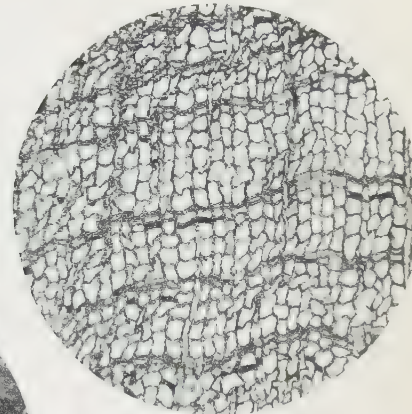

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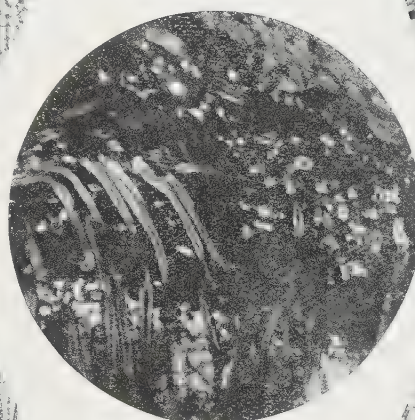

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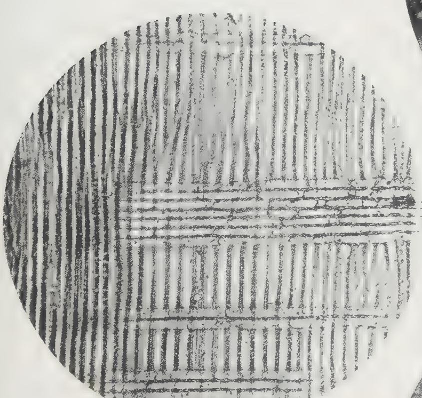

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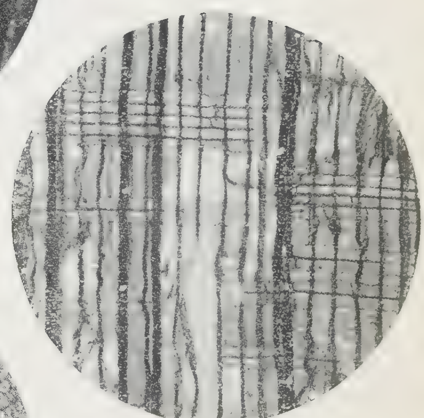

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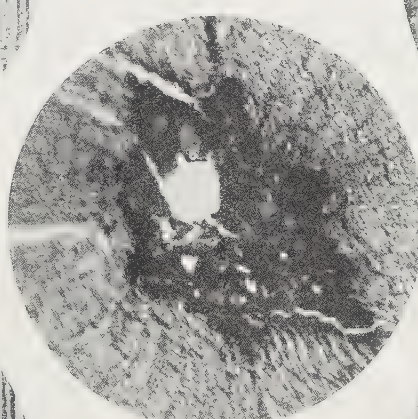

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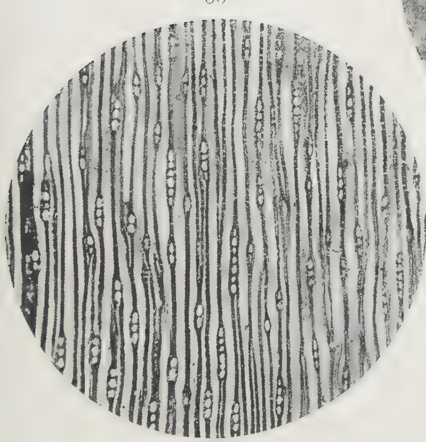

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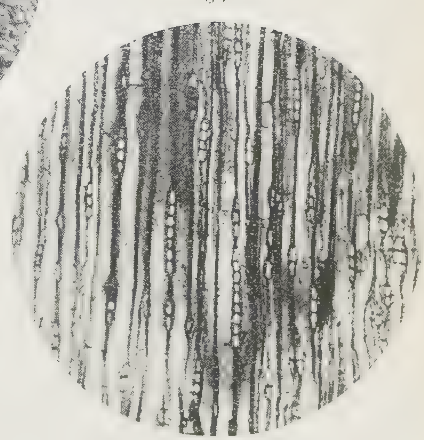

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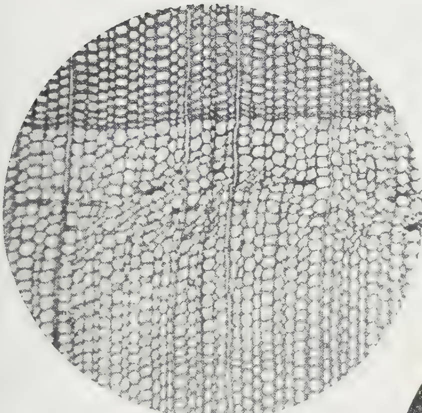

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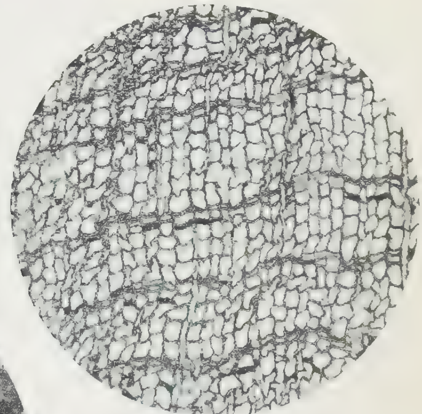

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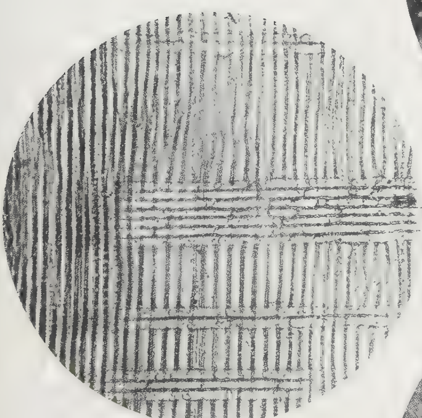

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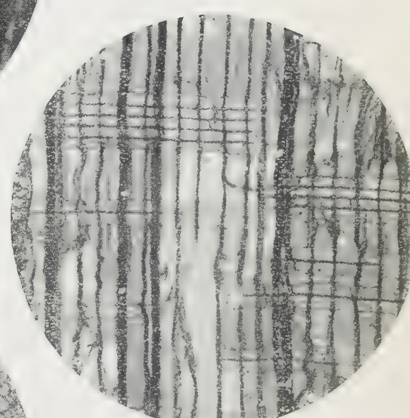

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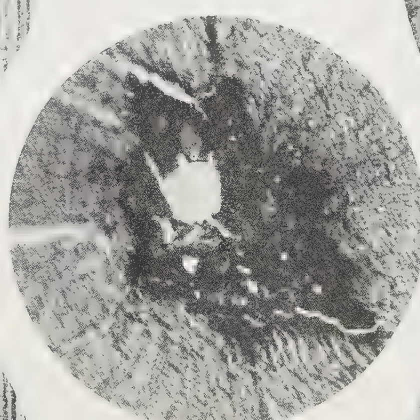

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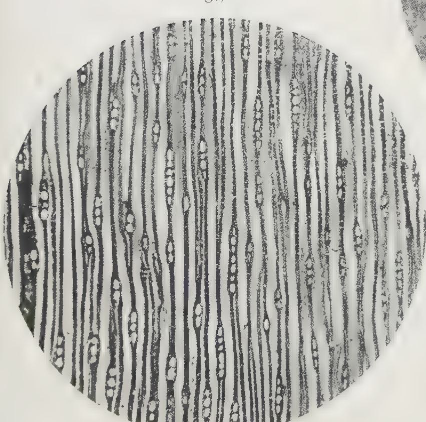

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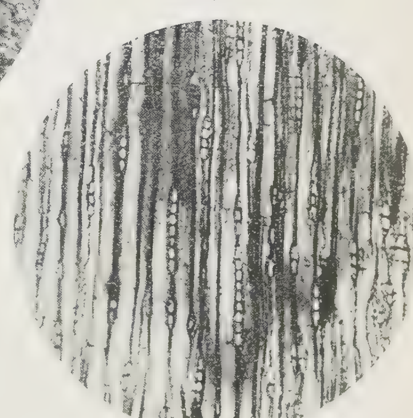

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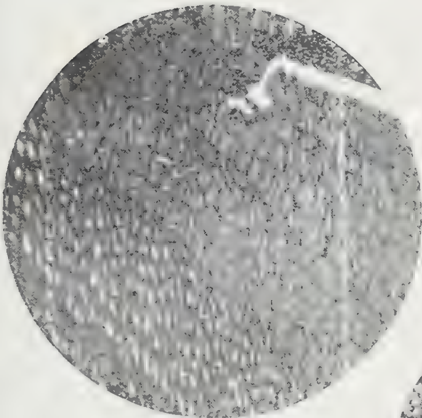

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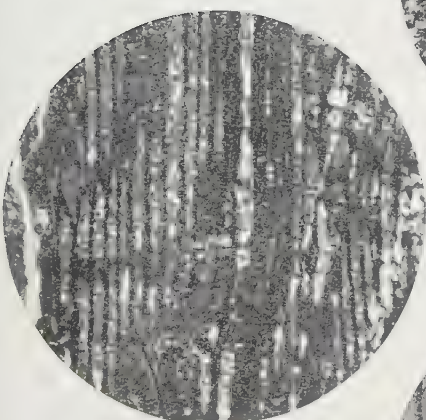

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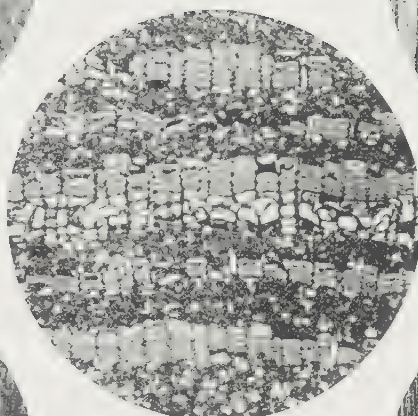

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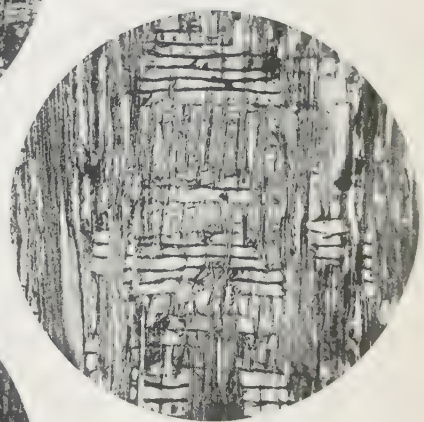

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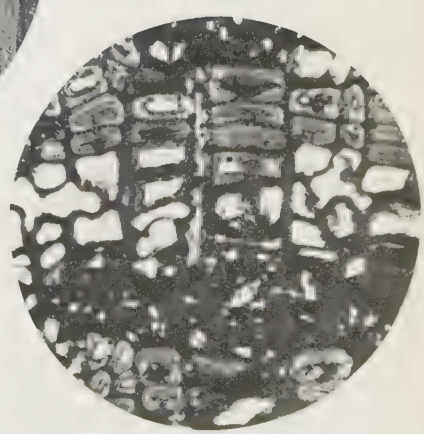

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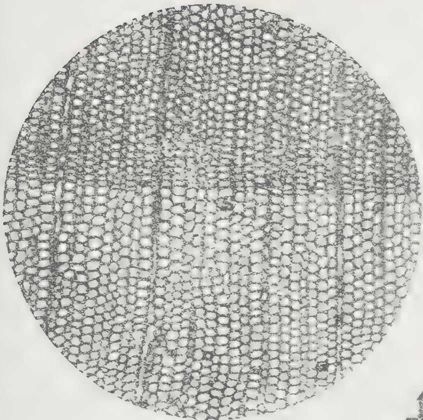

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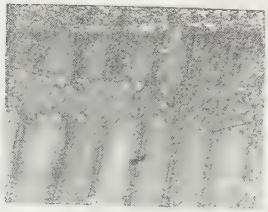

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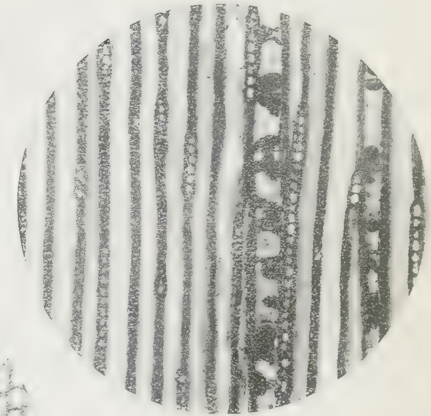

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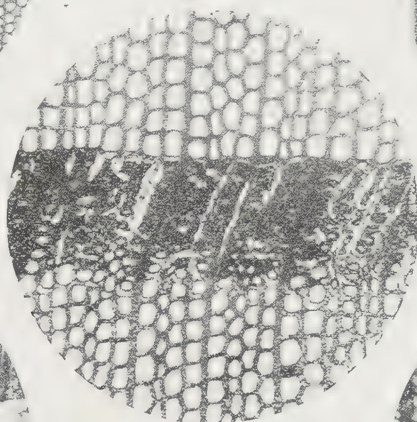

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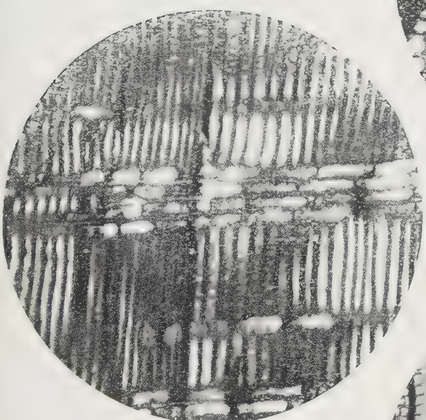

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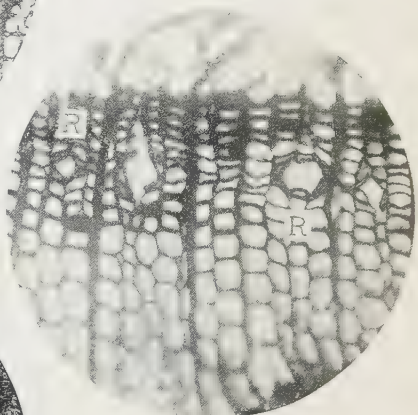

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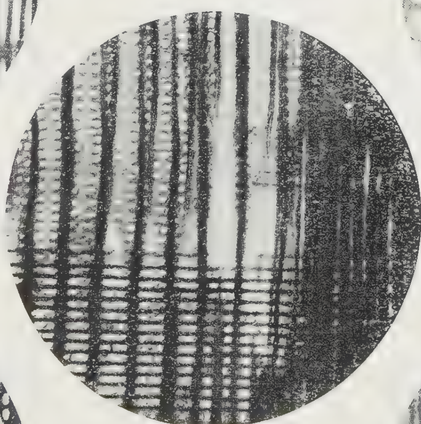

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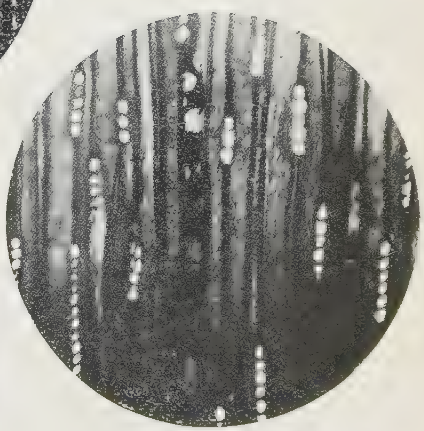

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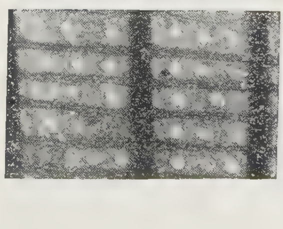

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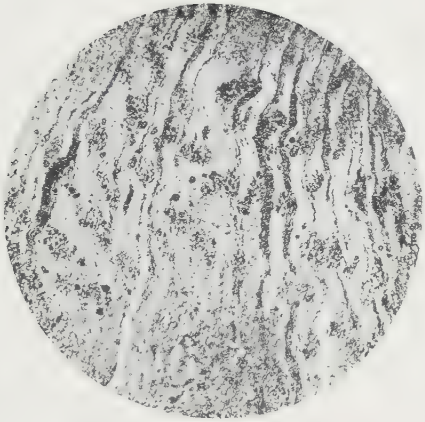

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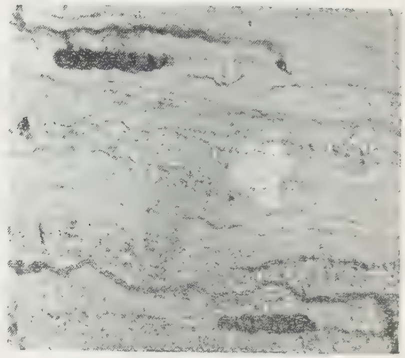

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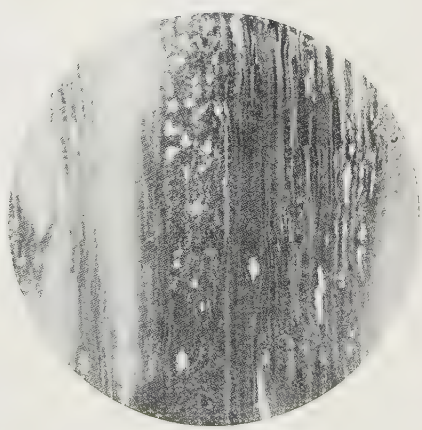

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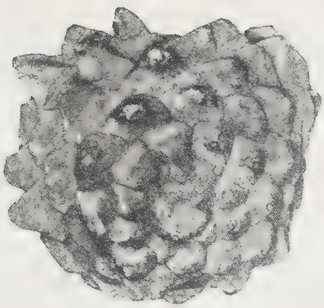

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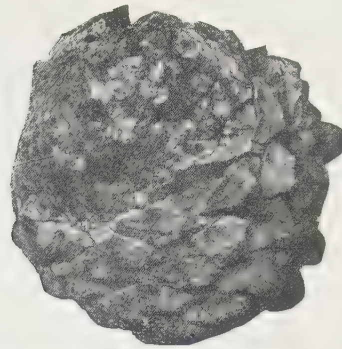

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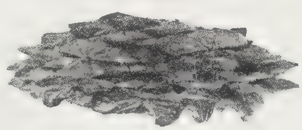

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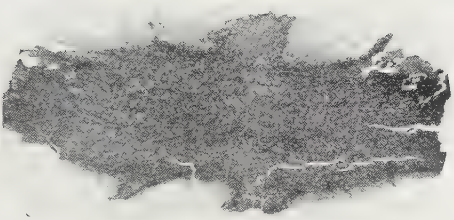

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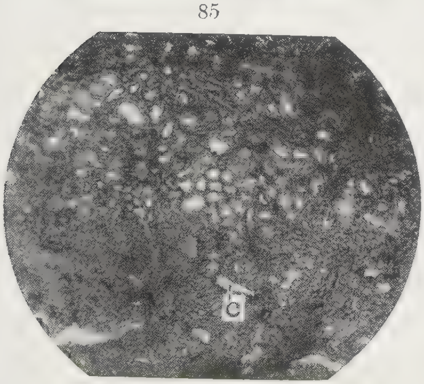

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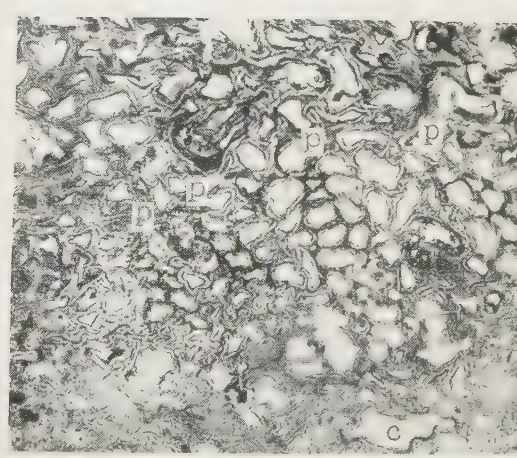

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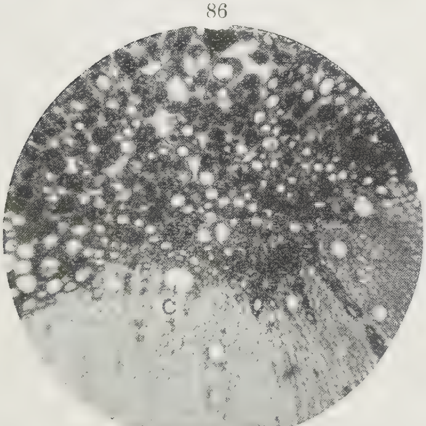

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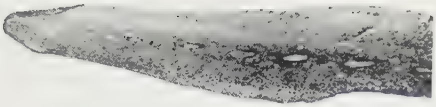

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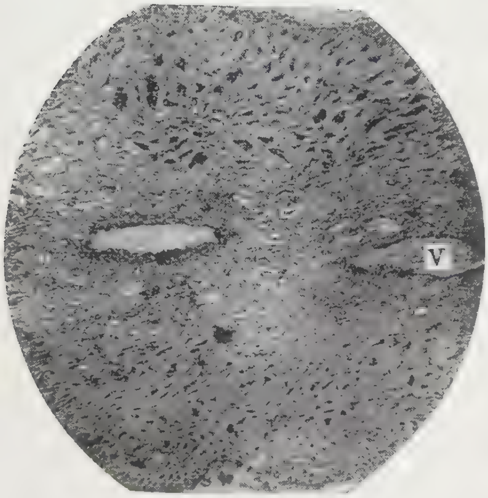

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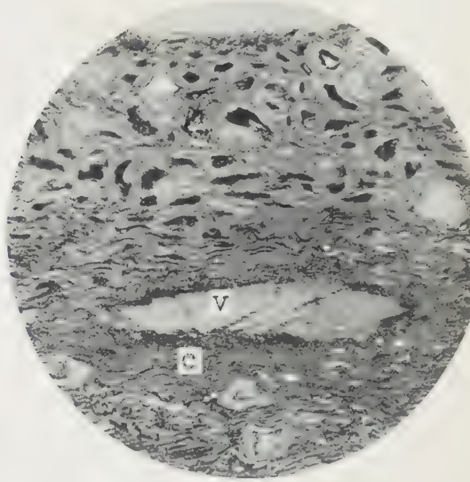

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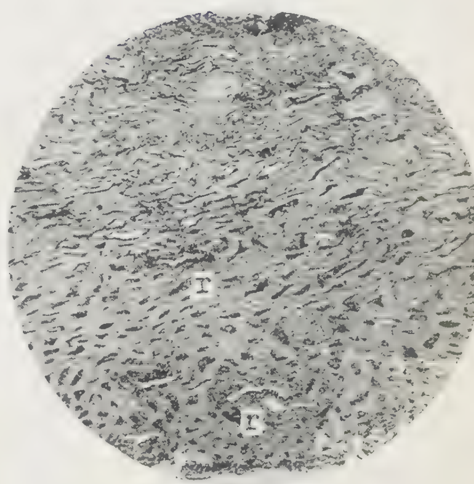

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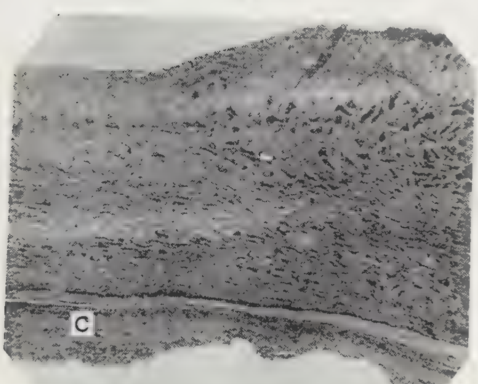

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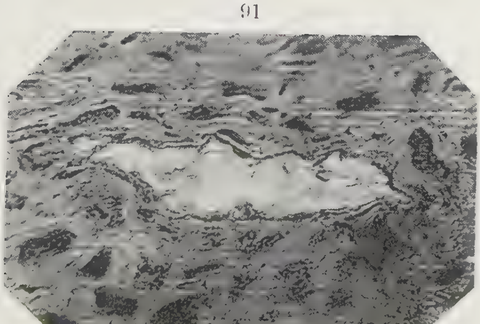

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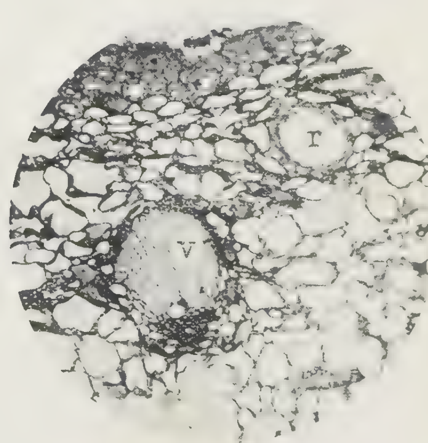

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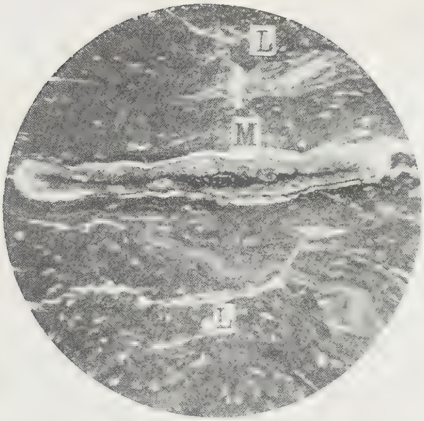

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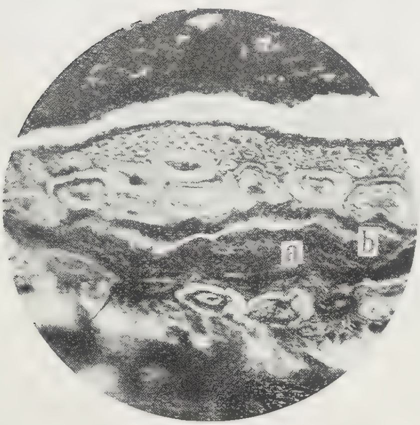

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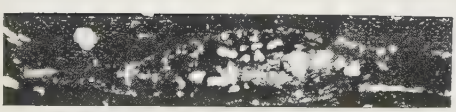

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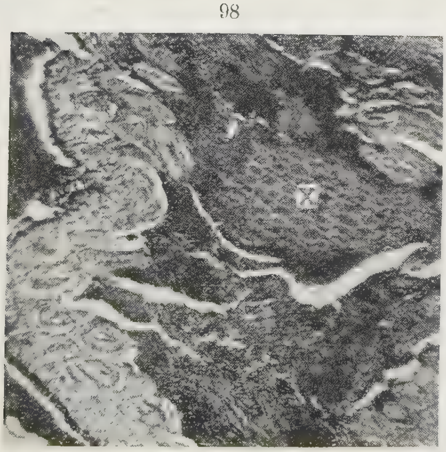

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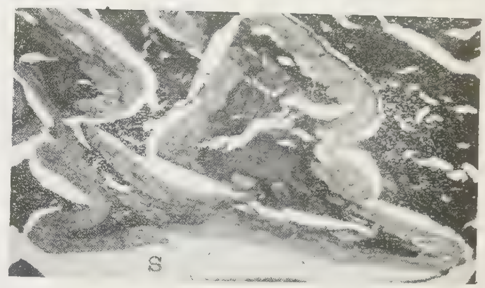

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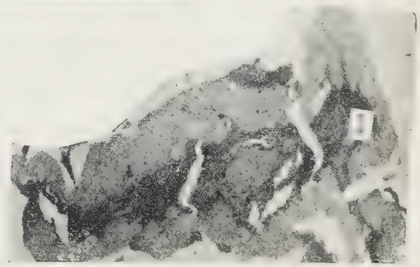

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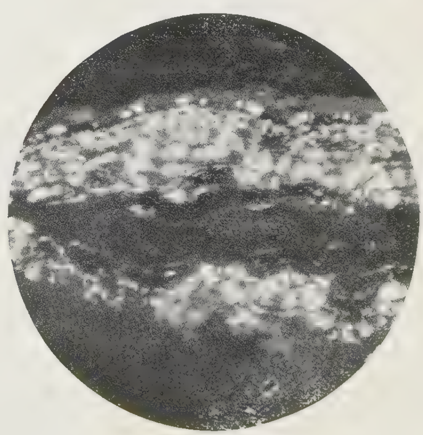

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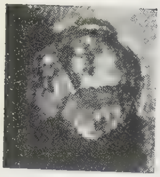

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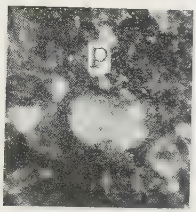

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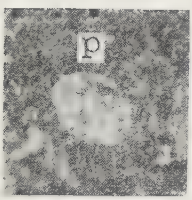

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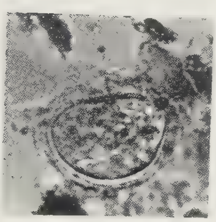

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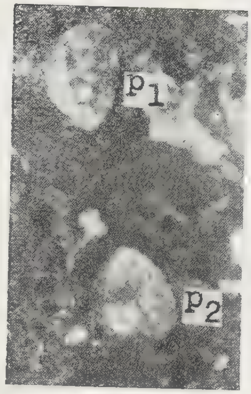

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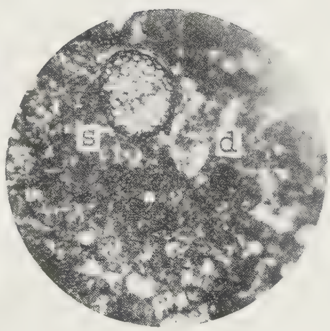

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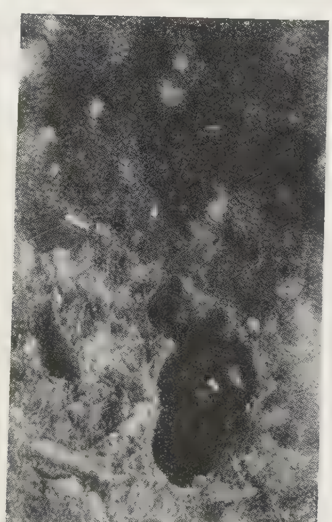

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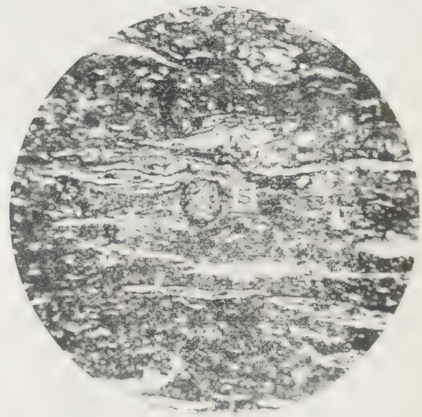

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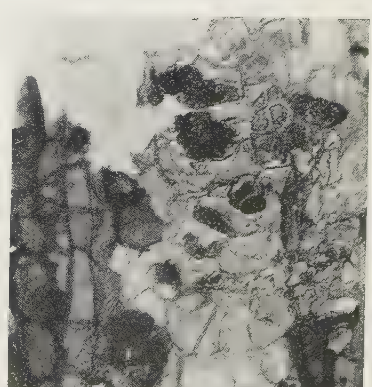

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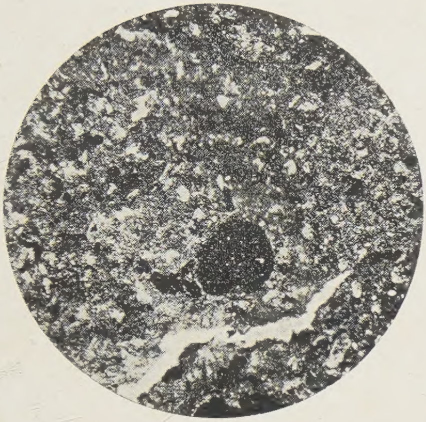

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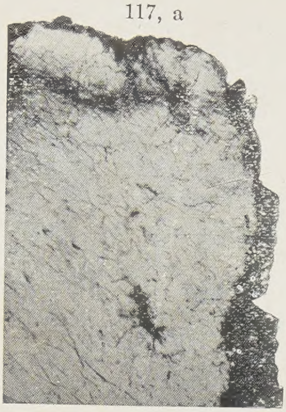

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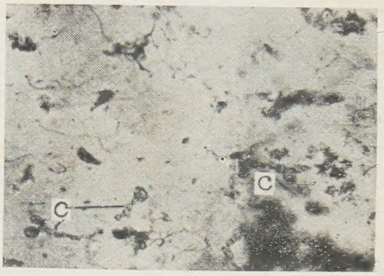

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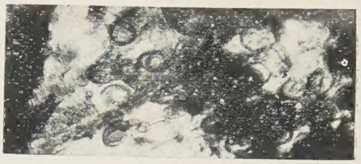

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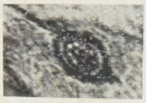

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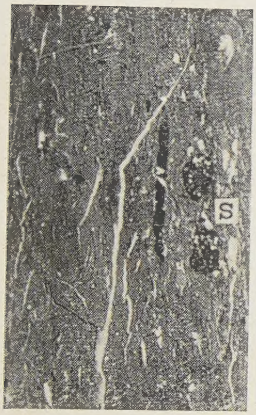

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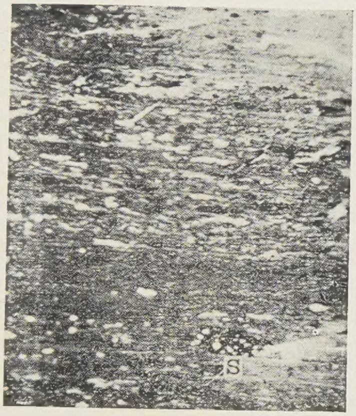

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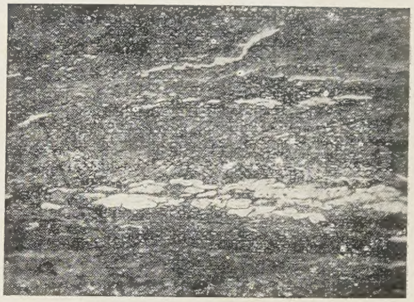

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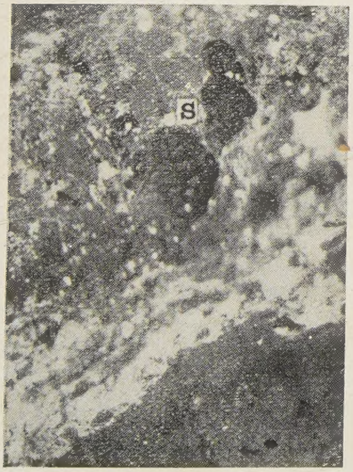

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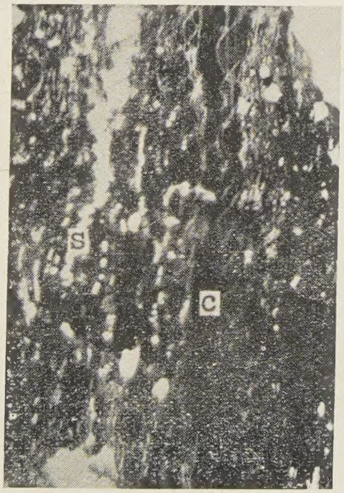

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